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Closed-Loop Theater TV
Color Reproduction
Time-Motion Study
16-Mm Film Maintenance
Theater Sound System
Cooling of Film
35-Mm Process Camera
American Standards
All-Purpose Film Leader
Progress Committee Report

THIS ISSUE IN TWO PARTS

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Part II, Five-Year Index

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A Comprehensive Proposal for a Closed-Loop Theater Television System

By R. L. Garman and R. W. Lee

Theater television offers tremendous possibilities to the motion picture industry as a new form of entertainment, but requires picture quality which measures up to the high standards of 35-mm motion picture practice. A totally new system is proposed which can produce the required picture quality. It differs from the home television system in several important respects, such as a higher number of scanning lines, a lower frame frequency, and greater video bandwidth. New electronic bandwidth-compression techniques may enable transmission of the improved picture over presently available relay facilities. Detailed discussion of the new standards and techniques points out advantages and possible disadvantages of this approach.

Sooner or later the motion picture industry must be prepared to develop its own television production facilities. Television techniques, because of their inherent convenience and artistic potential, appeal to producer and director on first inspection. They allow continuous program monitoring and immediate control of picture quality. Special artistic effects are readily created. Individual camera outputs can be combined at will to produce material with greater entertainment value than can be seen from any point on the studio floor. The television broadcaster has shown how valuable these techniques can be in creation of program material. The theater, however, must be prepared to offer considerably better picture and program material than is available to the home television viewer. The director, given adequate tools with which to work, can be relied on to produce program material of the necessary quality, but responsibility for picture quality rests with the equipment designer. At the very least, picture quality should be on a comparable level with the present high standards of 35-mm film productions.

The proposed GPL Theater Television System is the result of a basic study of the technical and artistic goals which can be attained in closed-loop theater presentation of television program material. This study was conducted with the firm conviction that television techniques available today, or on the immediate horizon, are capable of producing the quality of picture and program necessary for theater television.

Presented on October 20, 1950, at the Society's Convention at Lake Placid, N.Y., by R. L. Garman and R. W. Lee, General Precision Laboratory, Inc., Pleasantville, N.Y.

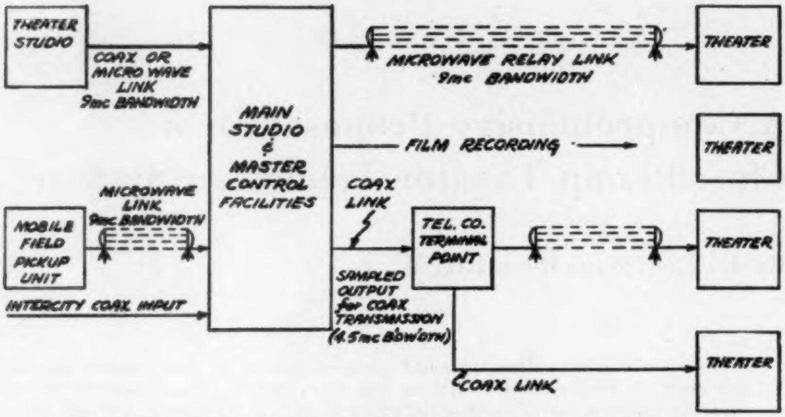

Fig. 1. Over-all system layout for closed-loop theater television.

It is realized that the practical system must represent a realistic compromise between quality on the one hand and cost and complexity on the other, and should be capable of conversion to color at a later date without wholesale obsolescence of equipment.

System Plan

Figure 1 illustrates, schematically, the broad outline of the proposed system. The master control facility is located in the building which houses the main studios. Remote program sources are linked to this central station by microwave relay. Programs are routed to theaters through microwave links (owned or leased) or via coaxial lines from a common carrier system. It will be noted that studio facilities for creation of live shows are provided. Main studio facilities include video recording equipment. This equipment provides a permanent film record of live shows so that film is available for later presentation, or for distribution to theaters not served by television transmission. Program control at the theater allows switching from central station program material to television broadcasts of special interest when desired. Program control at the studio allows selection of remote program material from a mobile pickup unit, the theater studio, or a syndicated program source other than the studio. Such syndicated program sources may be a logical future development.

35-Mm Motion Picture Quality

Complete specification of the quality of an imaging system requires detailed evaluation of the resolution, signal-to-noise ratio, contrast and transfer characteristics which can be realized. Fortunately, an analysis based upon resolution considerations alone can give considerable information. Such an analysis is not superficial, for, in general, the transfer characteristic, contrast and signal-to-noise ratio can be made nearly equivalent in film and television systems.

Schade,[1] in his very complete treatment of resolution factors, concludes that there is little difference in the inherent resolution capability of the 35-mm film system and an optimum 525-line 4.5-mc television system. The arguments are too lengthy to reproduce here in detail. Briefly, though, the analysis proceeds on the assumption that the resolution capability of any imaging system is the result of cascading

the resolution capabilities of a number of component parts and processes. In the film system, the cascaded components which enter the analysis are: (1) the camera lens, (2) the negative film, (3) the copying (positive) film and (4) the projection lens. In the television system, the components are: (1) the camera lens, (2) the camera tube, (3) the electrical channel, (4) the raster, (5) the kinescope and (6) the projection optics.

Schade's figures for the performance of component parts of system cannot be challenged, but his conclusion in regard to system operation is apparently based on a comparison between an *average* 35-mm film system and a *highly idealized* television system. Inspection of the material shows that it assumes: (1) the use of an experimental image orthicon with a 4½-in. diameter, (2) an experimental kinescope with a limiting resolution of 3000 lines and (3) ideal amplitude and phase correction in the electrical channel. Furthermore, the comparative ratings are based on the resolution obtainable at a point a few degrees off the axis of the system. The television and film processes are both charged with off-axis defects in the optical lenses. Off-axis defects in the electron lenses should be charged against the television system, but are not. Finally, a direct-projection theater television system includes a large-screen projection lens (probably of the Schmidt type) which is a significant limitation on resolution, while the comparative ratings are based on the quality obtainable with direct-view tubes.

One further consideration is important as affecting picture quality on a large screen. A television picture possesses line structure, and should be viewed at a distance large enough so that the eye integrates the line structure into a "flat" (continuous) field. With a picture containing 500 "active" lines, the viewing ratio (ratio of viewing distance to picture height) should be at least 4. In motion picture theaters, however, the viewing ratio varies from a minimum of about 1 to a maximum of perhaps 10. From this point of view, a 525-line television picture with a projected height of 15 ft will be of doubtful quality to anyone closer than 50 or 60 ft. Nearly 1000 (actually 975) scanning lines are required for a "flat" field at a viewing ratio of 2, 650 lines at a ratio of 3, and so on. Some improvement must be realized in this direction.

For these reasons, we conclude that the standard 525-line system cannot provide, on a large screen, picture quality equivalent to that of 35-mm film. Furthermore, because of the line structure, we believe that a 525-line system, even with increased horizontal resolution, is not satisfactory for theater television because it does not afford a reasonably flat field at viewing ratios less than 4. A higher line number is imperative for large-screen theater television.

Proposed Standards

As a result of a detailed study of all the factors involved, we are led to recommend the following standards:

Primary Standards

Frame frequency....	24 c
No. of lines per frame	675 double-interlaced
Line frequency......	16,200 c
Video bandwidth....	9 mc

Secondary standards

Vertical retrace time	5% of one field
Horizontal retrace time	20% of one line

Performance specifications

Effective signal-to-noise ratio (peak signal)/(rms noise).........	45 db minimum
Large-area contrast...	50:1 minimum
Detail contrast.......	20:1 minimum
Over-all transfer characteristic......	$E_i = E_0^n$, with $n \simeq 1.6$

Frame Frequency

The frame frequency of 24 c is proposed for two main reasons: (1) con-

servation of bandwidth and (2) compatibility with existing motion picture standards.

The proposed increase in line frequency for greater resolution necessitates a greater bandwidth, which is partially offset by reduction in frame frequency from 30 to 24 c. No greater economy is attempted because a frame rate appreciably less than 24 c would pose serious flicker problems. Even at 24-c frame rate, the 48-c large-area flicker frequency obtained in a double interlaced scanning system is just about the critical flicker frequency for the human eye, at a brightness level of 5 to 10 ft-L, with the phosphor decay characteristic of present-day picture tubes. There is reason to believe that phosphors with a longer decay characteristic and a very high efficiency will be available in the near future. Although it is probable that a 48-c field frequency is adequate to eliminate large-area flicker with presently available tubes, these new phosphors can be expected to eliminate the problem entirely.* With the aid of the new phosphors, interline flicker should be no trouble. Even with present phosphors the situation should be no worse, at a given viewing distance, than with the 525-line, 30 frame/sec system because of the larger number of scanning lines in the proposed system.

Pickup from film is somewhat simplified if the film and TV frame frequencies are equal; and is very much simplified in the case of flying-spot-scanner-continuous-motion-projector combinations.[2] This type of film equipment cannot be ignored, as it is now in use in France and England, where it produces exceptionally fine signals.

It may be noted that video recording at 24-c frame frequency poses different problems from those encountered in standard television at 30 c. The recording camera, if an intermittent type, must have a sufficiently fast pulldown mechanism to operate within the vertical retrace time. On the other hand, recording cameras of the continuous motion type are much simpler at 24 c than at 30 c.

The problem of satisfactorily fast pulldown mechanisms for intermittent cameras and projectors is not insurmountable. Simple extrapolations of conventional design in currently available mechanical intermittent mechanisms pull down film in approximately 15 degrees of shutter rotation. Completely new approaches to the problem now give promise of achieving pulldown in less than the minimum vertical retrace standard set by the FCC.

The most important reason for adoption of 24-c frame frequency is that the video bandwidth required for a given horizontal resolution at a given number of scanning lines is only 80% of that required at a frame frequency of 30 c. Taking into consideration all of the above, we feel that the adoption of a 24-c frame frequency is clearly justified.

Line Frequency

It is highly desirable that the line frequency be kept fairly close to the present 15.75 kc so that the same horizontal sweep circuits, sync generators and similar elements may serve for both theater and home television standards. Once the frame frequency has been chosen, selection of a line frequency resolves into a choice of the number of scanning lines. In this case, the number of scanning lines should be such that, at 24 frames/sec, the resulting line frequency is within a few per cent of 15.75 kc. For a double-interlaced system, the number must be odd. Then, in order that sync generators using frequency dividers may be adapted to the system, the number should be a product of small prime factors. The number 675 seems a logical choice. Its prime factors of 3 and 5 are easily implemented in a divider

* Note added at press time: A recent publication[7] from the Philips Laboratories at Eindhoven provides the latest available information on this subject.

chain. It yields a line frequency of 16.2 kc, which is only 3% higher than the present standard. The next highest such number is 729, which would call for a line frequency of 17.4 kc, or about 10% higher than the standard figure. A 5% vertical retrace, with 675 lines per frame, would leave 640 active scanning lines in the picture. Hence, a flat field would be preserved for viewing ratios as small as 3.

Accordingly, we propose a scanning line number of 675 lines/frame, interlaced two-to-one, and a line frequency of 16,200 c. This is sufficiently close to the home television standard that there need be no difficulty in operating studio equipment and receivers interchangeably between the two standards. Furthermore, appreciably higher resolution and an appreciably smaller minimum viewing distance are afforded by the 640 active scanning lines.

Bandwidth

There are very cogent technical reasons for restricting bandwidth. The video bandwidth limitation of transmission systems in the ultra-high-frequency and microwave region is a primary consideration. An even more pertinent restriction arises from the characteristics of the human eye. As long as the horizontal and vertical resolutions are approximately equal, the eye accepts an increase in either one as a contribution to the over-all impression of sharpness. But, as Baldwin[3] points out, the subjective impression of sharpness increases more and more slowly with respect to objective factors as the image becomes sharper.

Schade's concept[1] of an "equivalent optical aperture" provides a useful tool for correlating image resolution and bandwidth requirements when the number of active scanning lines is known. In keeping with this concept, degradation of detail signals is considered to be an effect caused by integration of signal flux within an aperture, and can be defined in terms of that aperture when the size and flux distribution of the aperture are known. The aperture may be either real or fictitious. Thus, while loss of resolution may be due to either a wide scanning aperture in an image dissector tube or a narrow frequency channel, the end effect is similar and may be evaluated in terms of a common variable. Each stage in a multistage process can, in general, be considered in terms of its particular equivalent optical aperture, and the cumulative effect of cascaded apertures can be evaluated by the rule of squared sums. The performance of a practical imaging device is specified numerically in terms of a "flux response factor," $\gamma \Delta \bar{\psi}$, which, being a measure of the effect of the aperture on square-wave response, is roughly analogous to the power vs. frequency-response characteristic of an amplifier.

The raster and the frequency channel can be considered as cascaded apertures. Schade's method and notation are applicable and will be used. For a raster with N_v active scanning lines, the flux response factor is 0.5 at a line number $\sqrt{2}N_v$. The equivalent optical aperture of an ideal frequency channel accommodating N_H horizontal lines has a flux response factor of 0.5 at a horizontal line number $1.75\sqrt{2}\,N_H$, when N_H is greater than 500. The cascaded value of these two apertures yields the theoretical limiting value of the equivalent aperture for which, in an ideal system with perfect components, the flux response factor is 0.5. The performance of the equivalent optical aperture of the 675-line, 24-frame system and frequency channel can be stated in terms of the line number, $\bar{N}_{0.5}$, at which the flux response factor is 0.5. The aperture defined by $\bar{N}_{0.5}$ is then the theoretical limit for an ideal system with perfect components. This value can be expressed as:

$$\bar{N}_{0.5} = \frac{1}{\sqrt{\frac{1}{2N_v^2} + \frac{1}{6.12N_H^2}}}$$

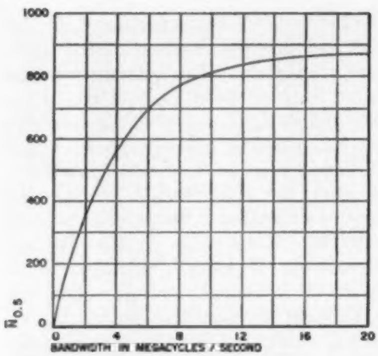

Fig. 2. Theoretical resolution capability determined by the equivalent optical aperture of an ideal 675-line, 24-frames/sec television system, as a function of the bandwidth.

This expression points up immediately the fact that the limiting value of resolution is $\sqrt{2}N_v$, even for infinite bandwidth (infinite N_H). Hence it is not economical to increase horizontal resolution indefinitely. A plot of $\bar{N}_{0.5}$ against bandwidth is given in Fig. 2, for $N_v = 640$, and 24 frames/sec, assuming the blanking times specified in the proposed standard. The figure of 9 mc which is proposed for the bandwidth yields a value reasonably close to the theoretical limit (800 lines, as opposed to 900). Increasing the bandwidth beyond 9 mc would not produce an appreciable increase in sharpness, particularly when one considers the further limitations due to components such as the camera tube and projection kinescope. However, the theoretical limit of the system is high enough so that the frequency channel and scanning raster chosen will not limit the performance when improved tubes are available.

The proposed system includes provision for dot interlace. This technique may enable reduction of the video transmission bandwidth to one-half that of the video bandwidth of the system, plus the width of the guard-bands and audio channel. For areas not equipped with transmission facilities providing the full bandwidth, it may be possible to use 4 or 5 mc relay equipment and coaxial facilities, both of which are now available, to transmit a picture with an 8 or 9 mc video bandwidth as an interim measure.

Secondary Standards

Little comment is required on the retrace times specified. The vertical retrace time is chosen with the idea of realizing the maximum practical number of active scanning lines without increasing unduly the requirements on intermittent film mechanisms which might be used in both ordinary and theater television studios. The horizontal retrace time is approximately the same as in home television, which means that horizontal deflection components and circuits can operate on either standard.

Synchronizing Waveform

A synchronizing wave-form standard has not yet been formulated in detail. The equipment in the theater must be designed to accept standard 525-line, 30-frame/sec signals off the air. This places no limitation on the ability of the equipment to take full advantage of the resolution afforded by a 675-line, 24-frame/sec, 9-mc signal. (A compatible standard seems to be quite simple in concept.)

Performance Specifications

The performance requirements have been deliberately made more stringent than those met by presently available systems. They thus serve as goals for further development.

The signal-to-noise ratio figure is definitely obtainable, if one is able to pay the cost, which is primarily the cost of studio lighting and of transmission power. The threshold of noise visibility on television pictures has been investigated by several groups.[1,4] It has been shown that the eye acts as a "low-

pass filter" to brightness fluctuations in the television image. Peaked-channel noise in which high-frequency components are predominant is therefore less visible than flat-channel noise, for a given measured ratio of peak signal power to noise power. This is the reason for specifying a 45-db *effective* signal-to-noise ratio, which means "equivalent to a 45-db signal-to-noise ratio with flat-channel noise." To achieve this ratio, the effective signal-to-noise ratio of the studio output signal and of the transmission channel (including the receiver, if one is used) must each be at least 48 db. The over-all effective ratio of 45 db may be compared with Schade's[1] observed threshold values of 50 to 55 db, and present optimum home television performance of 30 to 35 db, set by the equivalent signal-to-noise ratio obtainable with the image orthicon.

The contrast obtainable in television systems at present is not completely satisfactory, even for home entertainment, much less for theater use. This limitation is due almost entirely to the cathode-ray tubes currently employed, but research in this field shows that some improvement is possible in new tubes currently under development.

There is at present a vast confusion (or, more accurately, a lack of standards) on the subject of the slope of the over-all transfer characteristic (equivalent to "gamma" in the film process) for television. Long experience in the motion picture entertainment field has proved that, for best audience entertainment value, the over-all gamma of that process should be between 1.6 and 1.7. Theater television presents the same audience situation as for 35-mm motion pictures, and we have adopted the same criterion; that is, the relation between image-point illumination on the theater screen and object-point brightness in the original scene should closely approximate a power law with an exponent of 1.6 to 1.7. Furthermore, the studio output signal should follow a standard characteristic, which is approximately a seven-tenths-power law, to correct the picture tube characteristic to this value. In order to arrive at this standard characteristic, for signals from varied sources within the studio, variable-power-law amplifiers are required.

Choice of Components

The course of equipment development and system design raises fundamental questions regarding components to be employed. In particular, the type of television camera tube and the film size for recording and reproduction, whether 35-mm or 16-mm, must be decided. These two components dictate the characteristics and detailed design of a large part of the accessory equipment and also define the extent to which the stated performance specifications can be met. It will be well to consider these components at this point in the discussion.

Camera Tubes

The pertinent characteristics of the camera tube are:

(a) Shape of the transfer characteristic (plot of current output vs. light input);

(b) Signal-to-noise ratio as a function of scene illumination and lens stop; and

(c) Resolution.

Image tube sensitivity is commonly specified by a tube manufacturer in terms of the highlight illumination required on the photocathode, or in terms of the scene brightness normally used. However, the absolute sensitivity of any imaging system is measured by the scene brightness only when the angular field, depth of field and signal-to-noise ratio are known. Further, a comparison between highlight photocathode illumination figures is only possible if the photocathode areas are equal. But, when the angle of field, depth of field and scene brightness are specified, the ***total image light flux*** is fixed. The im-

portance of this figure has been emphasized by Rose[5] and others. A comparison between tubes may therefore be based on the total image light flux for a given signal-to-noise ratio.

The signal-to-noise ratio affects the quality of the picture viewed by the audience. One might expect that the signal-to-noise ratio could be neglected in a relative rating of camera tubes, but the point is that there is an important difference in the visibility of the noise spectrum associated with different types of tubes. The noise associated with tubes which contain a signal multiplier is flat-channel noise, or "white" noise. The noise associated with tubes which do not contain a signal multiplier is the noise at the amplifier input, which at the output is peaked-channel noise, with the high-frequency components emphasized relative to the lows. Since the high-frequency components are enhanced in peaked-channel noise, the filter effect of the eye is greater with "peaked" than with "flat" channels. Quantitatively, the following figures may be stated:[1] For the same measured ratio of signal voltage to noise voltage in a 4-mc channel, the visibility of "peaked-channel" noise is about one-third that of "flat-channel" noise. In a 9-mc channel, the visibility ratio is about one-sixth.

One further factor is pertinent to a comparison between camera tubes. Absolute sensitivities must be considered in terms of the studio light level required for a given lens stop. The assumption that camera lenses are set at $f/8$ will be convenient for calculating the illumination required. This setting provides very excellent depth of field and seems to be a conservative figure.

Any consideration of camera tubes for use in television must start with the image orthicon. The phenomenal sensitivity of this tube has made it completely standard in the American telecasting industry. The studio illumination required by the 5820 tube at a lens speed of $f/8$ is less than 100 ft-c.

Unfortunately, the maximum obtainable signal-to-noise ratio is not high. For commercially available tubes in a 4.5-mc channel, the figure quoted by the manufacturer[6] is 70:1 for the narrow-spaced variety (5655, 5826), and 35:1 for the wide-spaced (2P23, 5820). The current output saturates sharply at a certain maximum value of illumination. If the illumination on a narrow-spaced tube such as the 5826 is increased above this value, a picture is still obtained because of redistribution effects, but it is a picture of doubtful quality. Essentially, the design of the image orthicon has purchased extreme sensitivity by the use of: (1) a relatively low-capacity target and (2) low-velocity beam scanning, which limits the permissible element voltage. Both of these factors limit the stored charge and signal-to-noise ratio. Because a signal multiplier is used, the noise in the output is the combination of scanning beam noise and fluctuations in the stored charge, and is "flat-channel" noise. Hence, for a 9-mc channel, the average "effective" signal-to-noise ratio which can be guaranteed with commercially available tubes is 50:1, or 34 db, as against the 48 db required by the system specification.

There are other drawbacks to the use of the image orthicon. Spurious signals due to redistribution effects (black edges around highlights, the lack of cleanness in large black areas) are objectionable, and little can be done about them in the way of shading. The restricted range of the tube requires caution in lighting and compels the use of rather flat illumination in studio scenes. The limiting resolution obtainable in the standard-size tube is about 600 lines per picture height. Since the transfer characteristic is approximately linear, correction of the characteristic (black expansion, white compression) is prob-

ably required, with a resultant expansion of the noise in the blacks. Caution is required in the use of the tube to prevent picture "sticking" or "burn-in." Taking everything into consideration, with particular attention to the signal-to-noise ratio and resolution, it has been impossible to conclude that the sensitivity of the tube outweighs its other drawbacks, where the goal is high quality and high resolution.

Granting that there is no other tube which approaches the image orthicon in sensitivity, the question may be asked: what is the maximum tolerable light level in the studio? It can be assumed that the tolerable levels are those set by present motion picture film studio practice. Hence, the requirement which the camera tube should satisfy is that when operating at a light level of 500 ft-c, it must yield a satisfactory signal-to-noise ratio at a lens stop which yields the same depth of field as an image orthicon with the lens set at $f/8$.

If one disregards the iconoscope as being of unusably low sensitivity, the alternatives left are the orthicon and the image iconoscope. Tubes of the orthicon type suffer from instability at high light levels, and "smearing" or "streaking" for rapidly moving objects in the field of view. An image iconoscope, the Photicon, manufactured by Pye, Ltd., of Cambridge, England, seems to be best suited to the requirements and is our present choice.

The Photicon has the required sensitivity. Although higher light levels are required than with the image orthicon, an effective signal-to-noise ratio which meets the system specification of 48 db can be achieved. Since the Photicon does not use a signal multiplier, the noise level is set by the amplifier input circuit and the noise currents in the first stage, and is therefore "peaked-channel" noise. The visible effect of this type of noise is only one-sixth as great, for a 9-mc channel, as the visible effect of "flat-channel" noise. Hence, the specification of an "effective" 48-db signal-to-noise ratio requires a measured ratio of peak-signal-to-rms-noise in the Photicon channel of only 32 db. This ratio can be obtained at a lens stop of $f/5.6$ with less than 500 ft-c incident illumination on the scene. In considering this figure, it should be remembered that the depth of field obtained with a Photicon at $f/5.6$ is the same as that obtained with an image orthicon at $f/8$, because the size of the photosensitive area in the Photicon is smaller by about 40%.

The Photicon offers a number of other advantages. There is no problem of picture sticking. There is no saturation, but only a gradual white compression which is actually an advantage, since it obviates the necessity for a certain type of "gamma" correction which is required with the image orthicon, and eliminates the requirement for flat lighting. The picture is quite clean, requiring less shading than the iconoscope, and being free from the background signal, black rings around highlights and difficulties with large-area blacks encountered with the image orthicon. The resolution is not limited by mesh screens, and may be pushed as high as 1200 to 1500 lines.

For outside or mobile pickup, the image orthicon must still be used, for it is the only tube which has the required sensitivity.

Film Size

The extent to which film may be used in programming for a theater television system is a highly debatable point. Film is currently a major source of program material for home television. There are a number of good reasons why there should be less dependence on film in theater television. It is almost certain, however, that some film programs will be used, and hence film material must not be ignored.

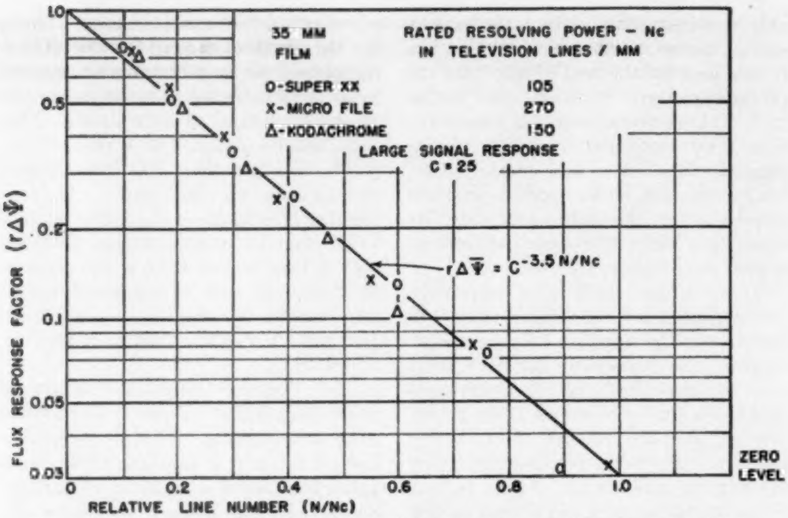

Fig. 3. General aperture response characteristics of photographic film for large signals (*Courtesy RCA*).

The size of film stock to be used, whether 35-mm or 16-mm, depends on the resolution capability of film. Schade[1] has made quantitative measurements of the flux response factor for film stocks as well as for components of the television system. In the case of film, this measurement is made by a television scanning technique labeled a "television microphotometer." The flux response factor is 1.0 at very low line numbers, and decreases more or less uniformly to zero at N_c, the limiting resolution. The original curve is reproduced in Fig. 3. The limiting resolution for Super-XX negative film is about 100 (TV) lines/mm; for Microfile about 270 lines/mm. The flux response factor is 0.5 at 21 lines/mm for Super-XX and 55 lines/mm for Microfile.

A flux response factor of 0.5 would not represent a severe limitation on system resolution. However, a flux response factor of 0.25 is, in practice, about the minimum which could be tolerated for any one step in the process. This figure can be obtained in a Super-XX negative at a line number of 45 lines/mm. One copying process onto fine-grain positive film reduces this figure to 38 lines/mm. This is just tolerable if 35-mm film is employed, for the frame height of 15.7 mm gives a practical resolution of just 600 lines. Of course, the limiting resolution is well in excess of this figure, something like 1100 to 1200 lines in the 35-mm frame. Without hesitation, therefore, we have proceeded on the assumption that 35-mm film will be used. It is required in a high-quality system.

Conclusion

The foregoing proposal is intended to invite comment and criticism, particularly in regard to the objectives outlined and the means chosen to achieve them. It is believed that the performance goals are realistic and realizable. A complete system of the type proposed, if implemented today with components which are currently available, can achieve a fairly close approximation to the ultimate performance goals. New

developments can be incorporated as the art progresses, within the framework of the proposed standards.

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Discussion

Otto H. Schade: Having been quoted a number of times in the paper, I would like to make some remarks and point out differences in opinion on some of the statements made.

Mr. Lee mentioned that I failed to include the off-axis resolution loss in television tubes while taking it into account for optical lenses. A justification for doing this in the quoted evaluation of a particular television system is the fact that electrical focus modulation can be used (as I have done) to maintain a perfectly uniform focus over the picture area in both camera tubes and kinescopes. This is, of course, not feasible for optical lenses.

I would like, further, to make some comment on the proposed frame repetition rate. A rate of 24 television frames per second can, in my opinion, lead to complaints with regard to detail flicker and more noticeable failure of interlace which occurs at certain rates of vertical motion in the television picture. Most of you have probably seen this effect on good television receivers, where, at times, the scanning-line raster seems to contain only one-half the number of lines when the camera pans up or down at certain speeds. This apparent failure of interlace is not caused by a defect in the electrical timing system but is due to optical and geometric effects resulting from the time difference of partial rasters in an interlaced system. The defect increases with picture brightness (reduced storage of the eye), decreased persistence of the kinescope phosphor, with decreasing frame rate, a lower raster-line number, and it increases further with the resolution of the system. The reduced brightness of a large-screen theater projection and the somewhat longer persistence of projection-tube phosphors are, hence, an advantage reducing the effect at a frame frequency of 30 cycles, but these advantages are perhaps more than canceled by reducing the frame rate to 24 per second. I would, therefore, suggest that a decision with regard to the proposed decrease in frame rate should be made only after comparative demonstrations have been given.

A reduction of the suggested frequency channel of 9 mc to 4 or 5 mc by the use of horizontal dot interlace appears, offhand, very attractive. The dot interlacing process effecting an increase of resolution in the horizontal direction, however, is based on the same principle as the increase of vertical resolution (line number) by the normal line interlacing process, namely, that alternate picture elements or lines only are reproduced in sequence, the reproduction of intervening elements being delayed in time. The picture repetition cycle is thus increased by vertical interlacing to two vertical scanning periods containing two sets of horizontal

lines. The addition of horizontal dot interlace breaks up the horizontal lines into a series of dots with intervening empty spaces to be filled out in the following two fields, a complete picture thus requiring four fields. The frame frequency is, therefore, reduced to one-half (i.e., 12 or 15 cycles for a normal frame frequency of 24 or 30 cycles, respectively). The effects of flicker and interlacing failure mentioned above now occur also in the horizontal direction and are considerably more evident because of the lower repetition rate and the more frequent motion in the horizontal direction. I do not think that a decision on horizontal dot interlace could be made solely on a theoretical basis considering a stationary pattern, unless extended to and substantiated by satisfactory demonstrations of moving subjects.

It should be mentioned that horizontal dot interlace for the purpose of gaining black-and-white picture resolution is very different from the dot interlace system used to add color information, because in the latter, dots are not omitted leaving blank spaces when scanning a line, but rather the color components of the kinescope light are changed at a corresponding rate.

I finally wish to make some comment on the performance of television tubes and, in particular, the image orthicon relative to other camera-tube types, as it seems to me that the figures quoted on image orthicons and camera tubes, in general, can lead to misconceptions and do not fairly evaluate and compare the true operating conditions and characteristics demanded of practical camera tubes. With regard to the resolution required of a theater television system, in general, which is to be equivalent to a 35-mm motion picture system, one can make the following simple analysis of component quality without putting a restriction on line numbers or frequency channel. From this analysis one can form a rough opinion how existing components and anything available so far in television system components compare with ultimate requirements. The one figure commonly known for the components of a motion picture system is their limiting resolution. Aside from the camera lens, which will be omitted because it is used in both cases, a good motion picture system uses Plus X negative film with a limiting resolution in the order of 1400 television lines (counting black and white lines) in the vertical frame dimension.

When mechanical errors in camera, printing and projection machines are neglected, the remaining elements are the fine-grain positive film with a limiting resolution of roughly 2800 lines and the 4-in. $f/2$ Super Cinephor projection lens which is 2400 lines on the same basis (2% response) according to a sample measured by myself. Comparing these motion picture components with corresponding television system components, a camera tube (replacing the negative film) having a resolution of 1400 lines, a kinescope (replacing the positive film) having a resolution of 2800 lines, and projection optics (replacing the Super Cinephor) with a resolution of 2400 lines would certainly give the same over-all result, provided the detail contrast decreases similarly as a function of line number toward the limiting resolution in respective components. This is approximately the case for the elements mentioned. Introducing now, in addition to these elements, a limited electrical frequency channel, it is obvious on an optical basis that the afore-mentioned components should resolve higher line numbers to maintain the same over-all detail contrast below the limiting resolution. It can be shown, however, that the limiting resolution itself is actually not very important in comparison with good detail contrast at lower line numbers. An increase of detail contrast can be obtained by providing a relative increase of amplification for the corresponding detail signals in the electrical system. This correction, termed aperture correction, is effective in the horizontal picture dimension but not in the vertical picture dimension. The use of a large scanning-line number in a given television channel reduces the horizontal resolution and results in a less effective correction of detail contrast than selection of a lower number of scanning lines which corresponds to a higher horizontal resolution and, at present, gives a better over-all result.

When resolution under normal operating conditions of a camera is evaluated, it is common knowledge that the sharp-

ness of the camera image can be quite inadequate when lacking depth of focus, even though the resolving power of lens, film or camera tube are excellent. For a given scene illumination and exposure time, the sensitivity of the camera tube becomes a controlling factor for the depth of field and degree of perspective which can be imaged sharply. The sensitivity of the image orthicon is fundamentally several times higher than that of the image iconoscope referred to by Mr. Lee. The image orthicon permits a smaller lens stop setting, a greater depth of focus and, therefore, actually a generally sharper image of scenes with good perspective even though the maximum resolution of the commercial image orthicon is not as high as the figure quoted for the image iconoscope. The figure for the latter, according to my measurements and experience, appears somewhat optimistic and is certainly varying considerably over the inclined image surface of that tube.

With regard to signal-to-noise ratios, R, obtinable with the image orthicon, I would like to mention that a ratio, $R = 75$, should not be considered as a limit, because as in all camera tubes the value R can be changed by changing the target capacitance. I have measured values of 135 on the type 5655 tube and as high as 180 on larger tubes with 4½-in. face plates, which, incidentally, have resolutions between 1500 and 2000 lines. A comparison of the flat-channel noise from an orthicon with the peaked-channel noise of an image iconoscope in a 9-mc channel made by Mr. Lee came out in favor of the image iconoscope.

Taking the quoted value, $R = 75$, for an image orthicon in a flat 4.5-mc channel, an increase to a 9-mc channel reduces the value to $R/\sqrt{2} = 53$. For an amplifier noise current of 0.0035 μa and the relatively high signal current of 0.14 μa from an image iconoscope, the ratio, $R = 40$, is obtained in a peaked 4.5-mc channel; which decreases to $R = 40/2^{3/2} = 14$ in a 9-mc peaked channel. For a theater system with a symmetric resolution of $N = 600$ lines, the relative visibility of peaked- to flat-channel noise is approximately 6 to 1 for a viewing distance of four times the picture height, as quoted from my paper, when including a kinescope with a 1000-line resolution limit which was found inadequate above and also by Mr. Lee. We have, thus, the value, $R = 53$, for the image orthicon as compared to an equivalent, $R = 84$, for the image iconoscope. For increased kinescope resolution, however, the equivalence factor decreases from 6 toward 3.33 and R decreases from 84 toward 46.7, which is then lower than the value for the above image orthicon as borne out by actual observations. The same change in favor of the above image orthicon takes place also when decreasing the viewing distance to two times the picture height and retaining the 1000-line resolution limit of the kinescope. The conditions for the British C.P.S. Emitron (an orthicon type) are a little worse according to published figures.

It was stated further that the transfer characteristic of the image orthicon is linear. This is a misconception arising from a test with a small spot of light in a dark background. Actually the operating characteristic of a properly exposed image orthicon has a gamma between 0.7 and 0.8, the value decreasing with exposure and depending on various other operating parameters.

Mr. Lee: It should be pointed out that the figures which have been quoted for image orthicon performance are simply those which are specified in the *RCA Tube Handbook* and the available literature. This paper is a technical proposal of a set of standards which we believe represent a reasonable compromise between cost and performance and allow for a reasonable raster and channel which leaves room for improvements in components, but which do not arbitrarily limit system performance. Since it is only a proposal, it represents, of course, a number of ideas which have not been completely tested.

We have tried focus modulation in camera tubes and viewing tubes with a certain amount of success. I agree that much better results are obtainable with the camera tube than with the viewing tube. I do not remember the exact numbers. We have never been able to agree with the conclusion that it is fair or feasible to say that the resolution of a television picture, taking into account both the camera tube and the viewing tube, is as good in the corners as it is in

the center. We simply don't have an answer as yet to the possible objection to the 24-cycle frame rate or the things which happen in the event of vertical motion. How much that objection can be compromised by care in programming I don't know. I have seen pictures on the BBC, for example, which operates on a 25-cycle frame rate, where vertical motion causes trouble. How serious an objection that is, I don't know, because first of all, we have not been able to make complete tests, and secondly, we don't know how much the objection can be vitiated by care in programming techniques.

Concerning the use of dot interlacing to conserve transmission band widths, the question is something to which we will not obtain the final answer until complete experimentation is possible. It may be, as was actually represented in the slide which showed the proposed over-all system in the first place, that a 9-mc channel will be required to relay a black-and-white picture from the studio to the theater. We don't know yet. I agree with Mr. Schade that the story, so far as dot interlace is concerned, is different in color and in black-and-white. Transmission of a good quality color television signal should be quite feasible in a 9-mc band width at 675 lines, and I see nothing fundamental in the standards proposed and equipment we are developing which will prevent us from using line interlace, dot interlace, frequency interlace or whatever other system may be proved satisfactory by large-scale experiment.

Leonhard Katz: Mr. Lee, I was wondering why, in your paper and in the committee reports which preceded it, there appeared to be no mention at all of the intermediate film projection system which is presently being used by Paramount and several large theaters. I think the system has been previously discussed and has a number of advantages. Can this system be used at all? There seems to be absolutely no consideration given to such a use. It is available now and does not use projection tubes. So, it might have some advantages.

Mr. Lee: There is certainly nothing in the standards which prevents the use of intermediate film equipment.

Mr. Katz: Has it been considered at all?

Mr. Lee: Yes. It has been considered. As a matter of fact, General Precision Laboratory has on sale now a 16-mm intermediate film system for use with a 30-frame, 525-line television system. Consistent with the remarks I have made on the resolution on film, 35-mm would certainly be required for a system of 675 lines and 9 mc. Consideration has been given to it. No final decision has been made. Direct projection has been brought up here because at present the projection tube represents a fairly serious limitation on resolution in the system. However, there is a very strong objection to the use of intermediate film if a good direct projection tube is realized. These objections are in terms of operating cost, particularly when 35-mm film is used in place of 16-mm, the necessity of having operators tend it, and so on.

Donald E. Hyndman: In answer to the part of the question in which you referred to the committee, I don't believe that we ignored or even compromised with either system. Actually, what we are now doing is studying distribution facilities which apply equally well to the film storage system and the instantaneous system. In other words, if it works for one, it should work for the other, obviously, and should be an advantage.

Quality of Color Reproduction

By David L. MacAdam

The evaluation of quality of color reproduction poses many complex problems. Optimum reproduction needs to be identified. Since it depends upon the limitations of the reproduction process, as well as upon human vision and judgment, optimum reproduction will probably have to be determined for each process separately. The program is to vary the production controls in systematic manners, measure the resulting color reproduction in the best way known (e.g., the ICI method at the present time), submit the reproductions to visual judgment, and study the judgment data in comparison with the measurements in order to find significant correlations. The growing experience of such studies of color photography is suggested as a guide. Preliminary estimates of optimum reproduction and of seriousness of deviations may be based tentatively on results of studies of noticeability of color differences and on fragmentary results of studies of color photography. These estimates can be improved as various parts of the program are carried out.

"*Complete theories do not fall from Heaven . . .*" (Freud).

When asked how he obtained such delicate flesh tones, in the nudes for which he is famous, Renoir is said to have replied, "I just keep painting and painting until I feel like pinching—then I know it's right." Color photography and color television are far from such perfection, but no better prescription for improvement can be written.

Judgment and measurement are indissoluble partners in the task of assessing quality of color rendering. Color can be measured, as can weight and height, but no formula can be trusted to distinguish pleasing from displeasing color, any more than a formula based on dimensions guarantees beauty of form. The principal value of measurements in such problems is that they permit something to be recorded about the occasion when satisfaction is experienced, or dissatisfaction expressed. The judgment, "I like that," is fundamental to all knowledge of what constitutes a good picture, but the knowledge is as evanescent as the picture if no measurements are made to record what the picture was, when it was approved. However, it is useless to make measurements blindly. The most revealing measurable characteristics of a picture, as of a beautiful form, can be discovered only by searching for whatever specifications are shared by all pleasing examples and more or less violated by less satisfactory ones.

Neither painters nor those in charge of color control in photography or television can hope to succeed by blind reliance on measurements. If a modern painter should venture to assert that

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he surpasses Renoir in the ability to render flesh tints, on the grounds that measurements prove his tints are closer to those of the living model, he would quite properly be dismissed with ridicule. Renoir's paintings do not, and probably never did, "match" the flesh of his models. This is not a criticism of Renoir, but an object lesson from which we should learn to investigate carefully before we rely upon "color-fidelity" measurements.

This article is concerned with only the evaluation of color rendering. It is not concerned with the dependence of color on other technical or economic considerations. Such considerations might be the dependence of color reproduction on the available frequency-band width, on the relative widths of the color-separation channels, or on fineness of picture detail, or the necessity of eliminating flicker and edge or registration defects. These factors are discussed at length by other authors. This article is not based on any acquaintance with television, but on experience in the application of color measurements to color photography.

This article can only outline the problem, and review the partial investigations that have been reported and are known to be in progress. Basically, the crucial questions are only asked, not answered. A program is suggested, modeled on one which seems to be productive in photography. No formula for the evaluation of the quality of reproduction is recommended. It is doubtful that any valid formula can be derived from the fragmentary and largely contradictory data now available concerning visual sensitivities and tolerances for color errors.

The Psychophysical Approach

There is nothing new in the suggestion that the quality of color in photography and television should be determined by visual observation and judgment. Nor is the idea of measuring the colors without precedent. The particular point of this discussion is that neither of these alone is adequate, but that a systematic combination offers the most promise.

The weakness of unaided judgment is shortness of memory. This is aggravated by the common tendency to jump to conclusions in order to aid memory. Without measurement there is no way of identifying, much less of remembering, relevant factors in the pictures judged or compared. Without written records, it is impossible to accumulate much experience.

The particular features of the design of picture-producing devices, and adjustments of the controls can, of course, be recorded. Although variations of these factors are convenient for sampling the enormous gamut of possible reproductions, these factors are not likely to be the most relevant measurable quantities for distinguishing good from poor rendering. The principles of color measurement, which will be briefly reviewed, are more likely than equipment design or controls to yield quantities which can be associated with the quality of color reproduction.

However, in themselves, color specifications lack any critical value. "Color fidelity," defined[1] as "the degree to which the television receiver reproduces the colors of the original scene," reveals a serious misconception of the purpose of both color television and color photography. This definition prejudges the facts, quite mistakenly according to present indications. Optimum reproduction can be identified only by asking a number of people to indicate their preference and relative ratings of a widely representative variety of color renderings, by measuring many colors in the pictures, and by studying the color specifications in comparison with the relative grades assigned to the pictures by the judges. The discrepancies between the colors of the preferred picture (the norm)

and those of the original scene may or may not be feasible to produce, but if such discrepancies are found, then "errors" of reproduction should be measured relative to the norm, rather than relative to the colors of the original.

Only after that norm is established can the question of the relative importance of various kinds of errors have any meaning. Such questions are important, and their answers are doubtless complex. They probably depend more seriously upon what the subject is, than upon its precise color in the original scene. Renoir's particular subject is not likely to be portrayed frequently in television or motion pictures, but human skin will probably be fairly high on the list of the most critical subjects.

Measurement of Color

In order to measure a quality, such as color, we must conceive it as depending on the values of one or more variable quantities, and our first step is to determine the number of variables which are necessary and sufficient to determine the quality of a color. No elaborate experiments are needed to decide that color can vary in three, and only three, independent ways. We can realize this by noting that color sensations can differ only in hue, saturation and brightness. If we adjust one color so as to produce the same hue, saturation and brightness as another, the two colors are indistinguishable.

For a very great variety of colors, such adjustment can be accomplished by varying the intensities of red, green and blue light combined in the same area, by simultaneous superposition or by juxtaposition in such fine patterns that the separate components cannot be distinguished, or by successive presentation at a sufficiently high rate so that the alternations of colors cannot be noticed. All hues and all brightnesses can be obtained in this manner. The only limitation is of saturation.

Very few, if any, pure colors from the spectrum can be matched with this scheme, and colors nearly as saturated as the spectrum are also unattainable. But practically all colors encountered in nature, art and industry can be matched. The range of saturation producible depends upon the particular red, green and blue chosen for the synthesis. The gamut depends somewhat on the hues of those components, but much more directly on their saturations. The greatest possible gamut would be obtained by using components as saturated as spectrally pure red, green and blue. Colors of even greater saturation than the spectrum can be imagined, and can even be experienced, fleetingly, for example, by viewing spectrum green immediately after prolonged viewing of a bright, saturated red. More important, the amounts of different sets of red, green and blue light necessary to match various colors are related by simple rules which can be extended to infer the amounts of physically impossible, supersaturated red, green and blue primaries, the mixture of which would match every obtainable color, including even those of the spectrum.[2,3,4] These rules have been applied to extensive experimental data on the amounts of ordinary red, green and blue components needed to match colors, and the results have been recommended by the International Commission on Illumination (ICI), and adopted by the American Standards Association as the basis for the measurement of color.

The principles of color measurement are shown in Fig. 1, where E represents the spectral distribution of energy incident upon a reflecting sample and R represents the spectral reflectance of the sample. The spectral distribution of the light reflected into the eyes of the observer is represented by the product curve, $R \times E$. If the spectral distribution of the light incident upon the eyes of the observer is measured directly, for instance, by spectroradiometry of

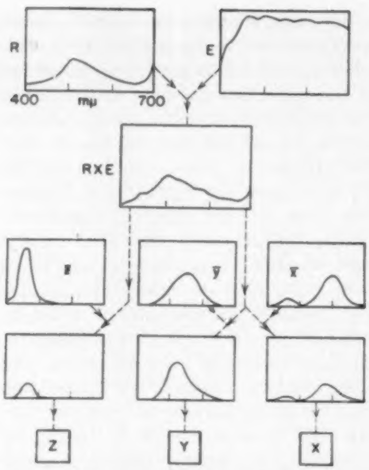

Fig. 1. Diagrammatic representation of principle of colorimetric specification.

the light from a television receiver, it can be used in place of the $R \times E$ curve. The standard ICI spectral-weighting functions, which correspond to normal human color vision, are shown by the curves, $\bar{x}$, $\bar{y}$, and $\bar{z}$. The areas under the curves which result from weighting $R \times E$ by the $\bar{x}$, $\bar{y}$, and $\bar{z}$ functions are the quantities, X, Y, Z, of the supersaturated ICI mixture components required to match the color of the sample. Routine methods of computation differ from this scheme only in details.[2,5,6]

In addition to including every color within their mixture gamut, the ICI components have the convenient property that the quantity, Y, specifies luminance (the photometric evaluation of brightness). The remaining two variables of color specify chromaticity, which is most conveniently represented by a point on a plane diagram. Such a diagram might be constructed by simply plotting Z vertically and X horizontally. If the ratios, Z/Y and X/Y, were plotted, however, all colors having the same relative energy distribution would be represented by a single point, regardless of their intensity, or luminance. This is a great convenience, since it enables us to study chromaticity independently of the intensity level. But the proportions of the resulting diagram are inconvenient. It is customary to plot, instead, the ratio, $X/(X + Y + Z)$, horizontally and the ratio, $Y/(X + Y + Z)$, vertically. The first ratio is abbreviated x and the second, y. The resulting diagram is shown in Fig. 2. The spade-shaped curve represents the colors of the spectrum, regardless of intensity. The straight line connecting its extremities represents the most saturated possible purples, from red at the right, through red-purples near the center to blue-purples and violet near the left corner. The curve tangent to the straight, long-wavelength (red) end of the spectrum locus and passing near the center of the diagram represents the colors of blackbody radiators* at various temperatures.

Since a blackbody at about 6500 K has nearly the same color as daylight, and household tungsten lamps operate at about 2800 K, any point near the corresponding segment of the blackbody locus may represent white, if the observer is adapted to the corresponding quality of illumination. This wide variation of the white criterion is an important fact. In one sense, it is fortunate because, for example, it permits the same motion picture films to be projected with tungsten lamps or with arc lamps of nearly daylight quality with very nearly equal satisfaction. Likewise, rather great variations of "balance" of color films and television pass unnoticed, provided that the picture controls the adaptation of the observer. However, if the surroundings are prominently illuminated,

* A "blackbody" is a source which radiates energy in accordance with Planck's formula.

fluctuations of balance, and even the standard of white adopted for the production of the picture, can be very objectionable. This is presumably not important in theaters, because the illumination of the surround can be controlled. Greatest tolerance of the audience is obtained if the surrounding illumination is quite subdued, so that the picture, and its accidental variations of balance can control the adaptation.

The problem is much more difficult in the case of home television, because the ambient illumination may vary in quality from daylight to that from amber decorative luminaires, and the level of ambient illumination must be sufficient for easy movement and even for reading by uninterested members of the family. The choice of a standard for white that will be least objectionable under all likely conditions of adaptation is very difficult. This is not so critical in the case of "black-and-white" pic-

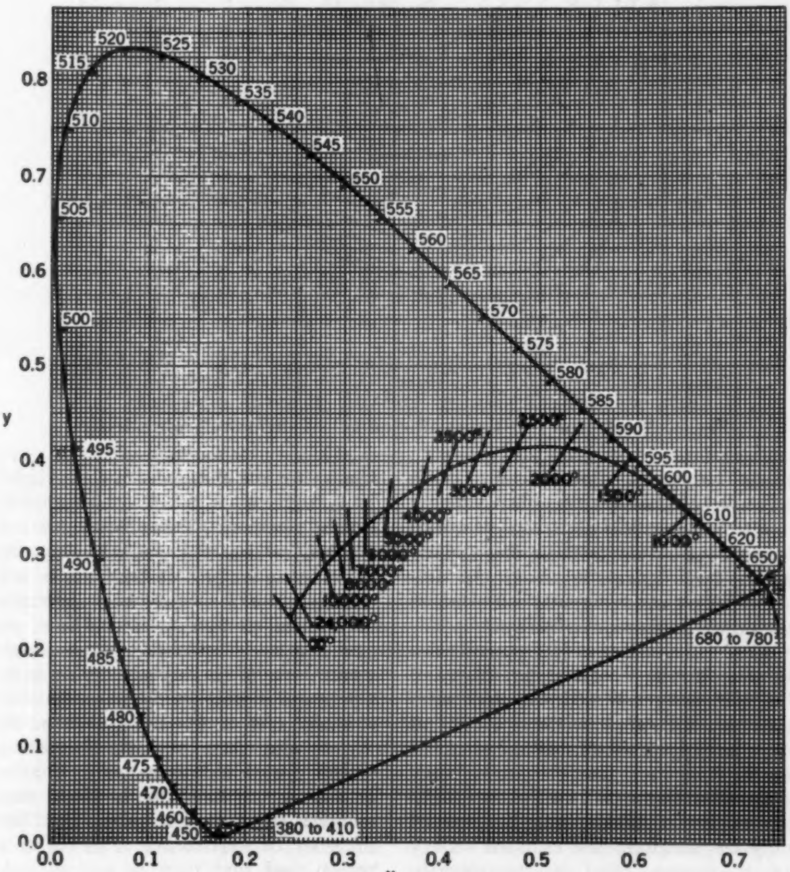

Fig. 2. Chromaticity diagram, showing locus of spectrum and locus of blackbody sources.

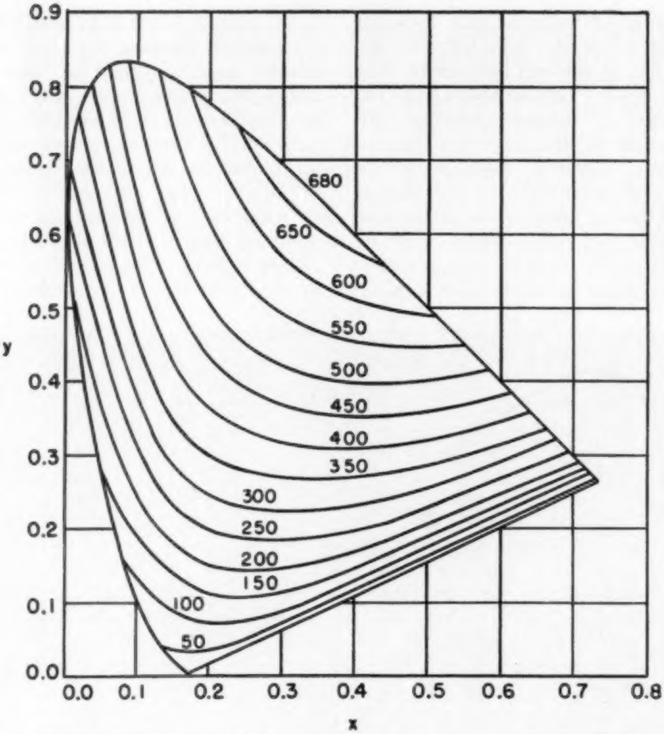

Fig. 3. Maximum luminous efficiencies of various chromaticities.

tures, for which observers are quite tolerant of "off-white" tints. It is much more critical for color pictures, because attention is then directed to color, and departures from the observer's ever-changing criterion of white distort his perceptions of all colors.

Figure 3 illustrates the general usefulness of the chromaticity diagram. On this is represented the maximum possible luminous efficiency of light of any desired chromaticity.[7] The maximum efficiency possible under any circumstances is 680 lumens per radiated watt. This maximum is obtained only by confining the radiated energy to a narrow band of wavelengths within a few millimicrons of 555 mμ. The maximum possible luminous efficiency for the chromaticity of daylight (x = 0.31, y = 0.316) is about 400 lumens per watt. This efficiency is not attained by natural daylight, nor by any existing lamps. It can be obtained only by use of a source whose spectrum is confined to two spectrum lines, at wavelengths 448 and 568.7 mμ. Such a source would be very objectionable as a practical illuminant, because it would seriously distort the normal colors of objects and the chromatic aberration of the eye would cause most objects illuminated with it to be seen surrounded by a violet haze. But the efficiency of that source is useful as a known goal that may be approached, but never exceeded, by a source having the chromaticity of daylight. Simi-

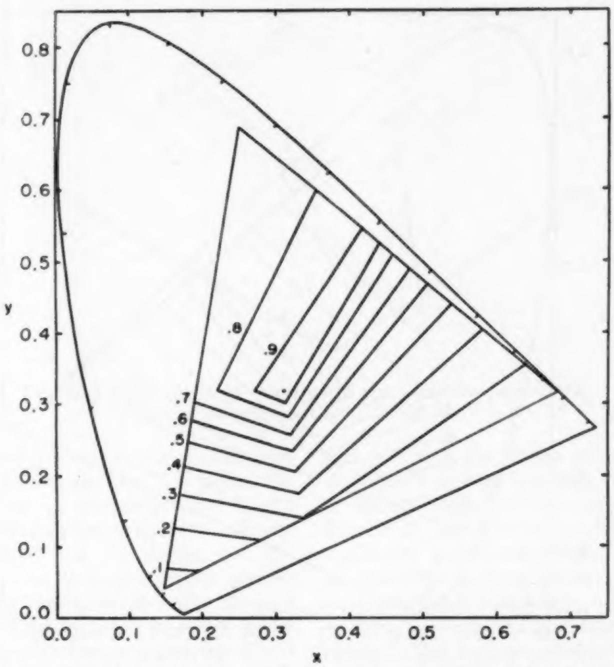

Fig. 4. Maximum luminances of various chromaticities producible by additive mixture of "C" primaries, based on assumption that maximum intensity of each is used to produce white.

larly, the efficiency indicated in Fig. 3 for any other chromaticity is a standard of comparison showing the amount of possible improvement in any practical case. It is interesting to note that, for almost all chromaticities, the maximum efficiency is obtained by adding 448 mμ to a second wavelength. This indicates, also, that the closer the blue primary approaches 448 mμ, the greater will be the luminous efficiencies of the chromaticities produced by additive combination of three primaries.

Similar diagrams showing the maximum possible luminous transmittances of filters having various chromaticities with daylight and tungsten light have been published.[8] From such data, Bingley[9] has computed the luminosities of two different sets of additive primaries required to reproduce the colors of the most efficient filters. Since the maximum efficiency has been closely approached only in the cases of a few yellow, orange and red filters, the requirements computed by Bingley are probably too severe.

The maximum possible luminous reflectances of colored materials having 2% minimum surface reflectance have been shown by Clarkson and Vickerstaff,[10] for tungsten lamp illumination. They also showed limits attainable with contemporary dyes. Probably those limits would be more realistic than the theoretical limits, for the determination of the maximum luminosity demands of additive primaries. However, the theoretical limits of luminous transmittance of filters, and of luminous reflectance

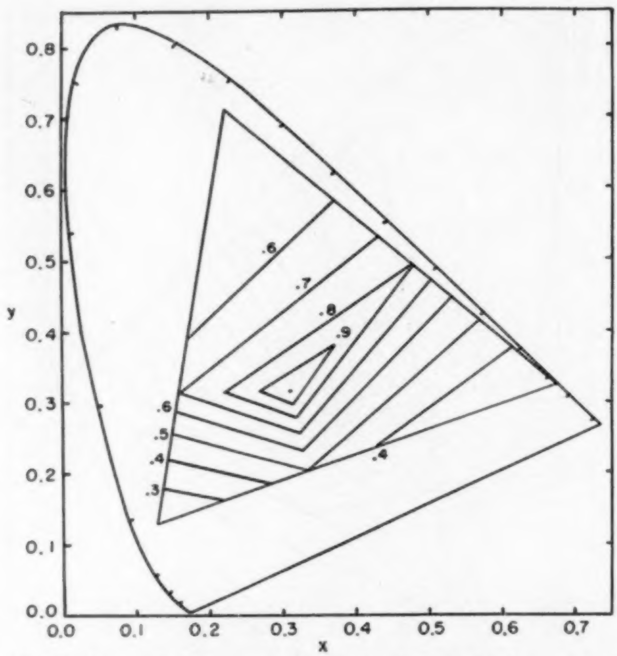

Fig. 5. Maximum luminances of various chromaticities producible by additive mixture of "A" primaries, based on same assumption as Fig. 4.

of colored materials having irreducible first-surface reflectance indicate the ultimate. The derivations on which they are based indicate the spectral characteristics that must be employed to attain the ultimate. Any other spectral characteristics necessarily produce lower luminous transmittance or luminous reflectance for any prescribed chromaticity.

The capabilities of a set of primaries may be shown in the manner indicated in Fig. 4, which, for some purposes, may be more informative than the diagrams that Bingley published. Figure 4 shows, for his "C" set of primaries, the maximum luminance with which any chromaticity can be produced, relative to white. It is assumed that the maximum usable intensity of each primary is used to produce white Figure 5 shows the corresponding diagram for the "A" set of primaries. Figure 6 presents a comparison of the chromaticity and luminance limits of these two sets of primaries. The lines indicating the luminosity limits in Figs. 4, and 5 may be regarded as contours of surfaces, below which are represented all colors producible by use of the corresponding set of primaries. This is illustrated in Fig. 6, which shows that the "ceiling" for the "C" primaries is above that for the "A" primaries in the green region (upper corner) and extends farther into the red, purple and blue regions (below), but that the ceiling for the "A" primaries extends slightly farther into the bluish-green region (to the left) and is higher in the

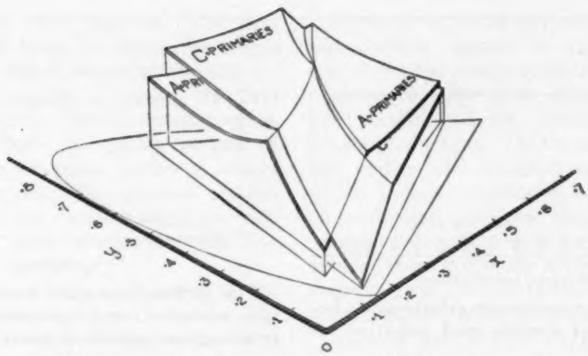

Fig. 6. Comparison of maximum luminances producible by use of primaries "A" and "C."

desaturated red region (right of center) than the ceiling for the "C" primaries. The ceilings are of nearly equal height (luminance) for desaturated blues (lower left central), but the ceiling for the "C" primaries extends to much greater saturations (down to the left). It may be interesting to note that the *Order* of the Federal Communications Commission, dated October 10, 1950, specified primaries which are very nearly the same as the "A" set.

The idea of a color space, suggested by this discussion, in which various luminances are represented by various heights above the chromaticity diagram, is very helpful in interpreting color measurements.

The luminance limits indicated by the contours in Figs. 4 and 5 are based on the assumption that white is the quality of the standard source, *C*, recommended by the ICI. As mentioned previously, this choice is arbitrary and might better be some other quality when the observers are not adapted to daylight, but the relations represented in Fig. 6 would not be altered seriously by any other reasonable choice of "white." The chromaticity gamuts indicated by the triangular boundaries in Figs. 4 and 5 are based on the assumption that a black of zero intensity can be realized and that any one of the primaries can be reduced to zero intensity, regardless of the intensities of the other primaries. The first assumption would not be applicable if any stray light from the surroundings is reflected from the screen, or if scattered light from neighboring portions of the image degrades the blacks. The second assumption would not be correct if there is any lower limit, other than zero, for the intensities of the primaries, or, in the case of a field-sequential system, if the persistence of the phosphor is so great that the image for one primary contributes appreciably to the luminance of the succeeding primary. In such cases, calculations of the kind used by Clarkson and Vickerstaff for dyed materials would be required to find the actual limits of chromaticity.

Returning now from this digression, concerning the general utility of the chromaticity diagram, we summarize the possibilities and limitations of color measurements. The physical factors of color can be measured by use of spectrophotometers and spectroradiometers. The psychophysical specifications of color can be determined by use of the principle illustrated in Fig. 1. But these specifications are, so far, devoid of critical sense on which judgments of picture quality might be

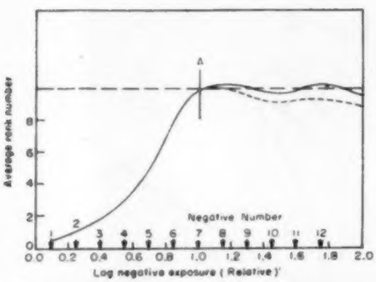

Fig. 7. Approximate relationship between print quality and negative exposure.

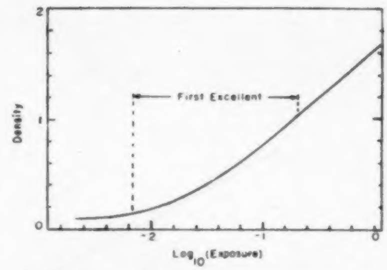

Fig. 8. Sensitometric curve of negative material, and exposures used in making first excellent print.

based. The problems remain, of discovering the proper "aim-points" for color rendering and of devising some way of evaluating discrepancies of actual color rendering from the optimum rendering.

Psychophysical Evaluation of Tone Rendering in Black-and-White Pictures

A great deal of work has been done and more is in progress, for the purpose of answering the above questions for color photography. The problems are not yet solved and few partial answers can be even suggested. It seems reasonable to expect, however, that a method of investigation which appears to be fruitful in color photography may also be useful in color television. That method is an extension of the method of investigating the quality of tone reproduction, which has been found successful in the case of black-and-white photography. The method and its potentialities can probably best be appreciated if that successful application of it is reviewed.[11]

Many variables influence the quality of black-and-white photographs. One which has been studied very thoroughly is the exposure given to the negative. Study of this case is important, because it provides a functional criterion for rating the speeds of various negative materials.

A certain scene was photographed repeatedly, using exposures varying by moderate steps, ranging from definite underexposure to definite overexposure.[12] All these negatives were made on the same kind of film and were developed identically. From each negative a series of prints was made, on several grades of paper. Each negative was printed on each grade of paper with definitely more and definitely less exposure than was desirable, and with several intermediate exposures.

The complete set of prints from each negative was submitted to a number of people, working separately. Each selected from the set for each negative the print he preferred. When the selections were compared, they were found to agree remarkably well. Finally, the judges were asked to arrange the best prints from all negatives of a single scene according to tone quality.

The results in one case are shown in Fig. 7, in which the average rank of each print is plotted as a function of the exposure of the negative from which it was made. The print judged poorest by each judge was given zero rank, and successive digits were awarded to successive prints, in the order of improved quality. Beyond about the seventh print, the average rank number fluctuates inconclusively about a constant value, indicating that no significant improvement results from greater

exposure of the negative. The first print, A, of those for which the judges could not report reproducibly any increase of quality, is called the first excellent print. Similar exposure series, print selections and quality judgments were made for many scenes of widely different types. The physical characteristics of the various negatives were measured, and compared with the judgment results.

The main result, the answer to the original question, is indicated in Fig. 8. This shows, in relation to the curve representing the density of the negative material as a function of exposure, the exposures used in making the first excellent print of one of the scenes. Other scenes, which had greater or less ratios of maximum to minimum luminance, required, of course, more or less of the exposure scale than indicated in Fig. 8. Study of the relation of the exposures used in producing the first excellent print in each case revealed that the minimum exposure should be that for which the slope of the D-vs.-log E curve is 30% of the average slope of the portion of the curve used for the average picture. This criterion was found to predict successfully, for average conditions, the least exposure required to obtain negatives from which excellent prints can be made. It has been made the basis for the American Standard method for determining photographic speed and speed number.[13] It was not derived from purely physical principles, nor could it have been. Picture judgments, considered together with the sensitometric measurements indicated in Fig. 8, were necessary for the establishment of this criterion.

Similar judgments, considered in relation to physical measurements of picture characteristics, are doubtless necessary for the determination of important production variables, and ultimately of indices of reproduction quality in both color photography and color television.

However, an index of quality of color reproduction cannot be expected as one of the first results of such a program of research. No such index has yet been established for black-and-white tone reproduction. On the other hand, the earlier and more direct results, which indicate optimum adjustments of production variables, are at least as valuable as would be an index of quality. Such an index is of little more than academic interest when the optimum method of reproduction is known and used.

Another part of the study of black-and-white tone reproduction should be mentioned here, because a similar problem and outcome may be expected in color photography and color television. The straight line, A, inclined at 45° in Fig. 9, indicates exact objective reproduction of the luminances, B_o, of a scene, in which the ratio of maximum to minimum luminance is 100. The luminances of both the scene and the reproduction are shown on logarithmic scales. Curve B shows the tone reproduction obtained for that scene by using good photographic techniques. This curve shows the luminances in a picture printed on a semimatte paper. It is apparent that the ratio of maximum to minimum luminances in this print is considerably less than the luminance ratio in the original scene. Consequently, at least some of the luminance contrasts, $\Delta B/B$, in the original scene must be decreased in the print. It might be presumed that the best compromise would be to decrease all luminance contrasts in the same proportion. Such reproduction is represented in the logarithmic plot in Fig. 9 by the straight line, C. Curve B, which represents a print of very good photographic quality, does not follow this straight line. Slopes lower than 45° indicate reduction of luminance contrast in the corresponding range of luminances. It is evident that reduction of contrast is greatest in the high-

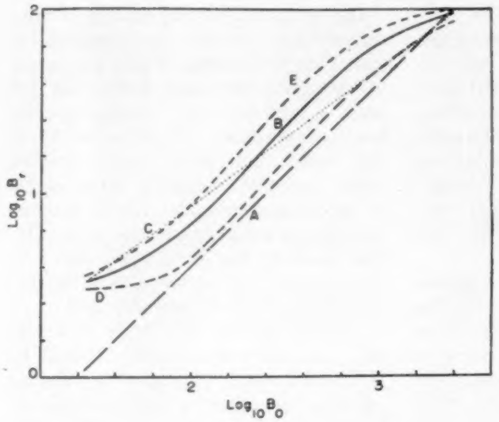

Fig. 9. Tone reproduction curves:

A, "exact reproduction"
B, optimum attainable with semimatte paper
C, proportional reduction of luminance contrasts to fit density range of semimatte paper
D, tone reproduction suitable for scene in which highlights are predominant
E, tone reproduction suitable when only shadow details are important.

lights and shadows, while the middletone contrasts are nearly the same as those in the original scene.

It is interesting to note that photographic limitations are not entirely responsible for the discrepancy between objective reproduction and preferred reproduction.[14] According to Jones,[15] "there are many cases where we know that the perfect objective reproduction, although obtainable, is not the one the majority of judges will choose as of best photographic quality." This effect is real and significant in magnitude. It must be taken into account if the best quality of reproduction is to be obtained. It may be due to subjective as well as objective differences between the situations within which pictures and real scenes are observed. Only a few types of conceivable differences need be mentioned: surroundings, restrictions of field of view, modes of perception (of flat pictures rather than real objects), attitudes, emotions and desires. Jones has shown that the differences of visual sensitivity to luminous contrast caused by quite different conditions of adaptation when viewing the print than when viewing the original scene, must also be taken into consideration.[11] Even if we could account for the effect, we could not neglect it, nor assume that objective reproduction is preferable to any other.

The fact that the print corresponding to Curve *B* is superior to Curves *D* and *E* could not have been determined from the curves alone, nor from any other representation of the results of purely physical measurements of the prints and the original scene. The best print was chosen by inspection, and rules for judging quality of reproduction from curves such as Fig. 9, or from curves showing the compression or expansion of contrasts can be established only by comparing the results of print judgments with the curves. Such rules are therefore psychophysical.

Without psychophysical relationships, the results of optical measurements tell little about the quality of tone reproduction. Such relationships must be rather complex, because curves similar to *D* in Fig. 9 represent optimum reproductions of some scenes, in which all the important details are of high brightness, such as open beach, desert or snowy landscapes. Likewise, prints with curves similar to *E* are best for subjects in which all the important objects are dark. In a qualitative sense, it appears that the objectionability of the compression of luminance contrasts should be weighted by some measure

of the importance of various parts of the luminance scale in reproducing each particular scene.

Investigation of Quality of Color Reproduction

The quality of photographic color reproduction is being studied by a method based on the same principles as were used in the investigation of tone reproduction in black-and-white photography. Series of pictures of a single scene are made with systematic changes of production variables. These pictures are then submitted to a large number of judges, working separately. Measurements are made of all optical quantities that seem relevant. The data from several scenes of different types are used to search for general correspondences between the judged quality of the reproductions and the optical specifications.

The investigation of color photography is much more complicated than that of black-and-white photography, because of the greater number of production variables as well as the greater variety of perceptions. The number of noticeably different tones in a monochrome picture is of the order of a few hundred, while the number of noticeably different colors (including all distinguishable tones of each chromaticity[16]) in a color photograph may be several million. This enormous increase arises from the fact that color photography deals with three independent variables, whereas monochrome reproduction involves only one. The number of distinguishable possibilities in color photography is of the order of the cube of the number in monochrome photography. It is somewhat less than the cube, because not all combinations of the three variables are possible, and variations are not equally noticeable in each of the three variables, nor independent of the values of the others.

Good tone reproduction is just as important in color photography as in black-and-white, but its control and measurement are considerably more complicated. Similarly, the other two variables of color which may be specified by chromaticity are much more complex to control and measure than was the single variable, luminance, in monochrome reproduction.

Some of these complications, especially those of production control, are peculiar to subtractive color photography, in which the optical primaries cannot be modulated independently of each other. Each of the three dyes, which are superimposed to make the picture, absorbs two or even three of the primaries.[17,18] In this respect, at least, color television should be less complex to control and measure than color photography.

The desire to separate the problem of evaluating the quality of color reproduction into two parts, tone reproduction and chromaticity reproduction, is understandable. If successful, it would greatly simplify the questions. But the possibility should not be taken for granted. The problem is not merely simplified; it is changed, and perhaps changed so as to have little relevance to practical color reproduction. Having recognized this danger, we can proceed to examine two attempts that have been made to evaluate color reproduction, both of which have been based on this subdivision of the problem.

In Annex *E* of the Condon report,[1] Judd, Plaza and Balcom assumed that optimum tone reproduction requires the luminances in the reproduction to be proportional to the luminances in the original scene. For their "index of color fidelity," they took the factor of proportionality to be such that white was perfectly reproduced. They then evaluated the errors of reproduction of the luminances of other colors by subtracting the corresponding Munsell values in the original scene and in the reproduction. Munsell values specify

perceptually equal tone differences by equal numerical differences. The method of Judd, Plaza and Balcom[1] heavily penalizes distortions of the ratios of greatly different luminances, which tone reproduction studies have shown to be relatively unimportant, and disregards compressions of luminance contrasts ($\Delta B/B$) which have been found very objectionable, especially in particular portions of the tonal scale that are important in the portrayal of the subject.

After considering many conceivable ways of evaluating the quality of tone reproduction in monochrome pictures, Jones[12] has tentatively suggested that it should be evaluated in terms of departures of luminance gradients from the optimum possible with available materials, rather than in terms of discrepancies of densities (or, presumably, Munsell values) from the densities of the optimum possible reproduction. The enormous amount of data he obtained on the optimum possible tone reproductions of several hundred scenes has not been studied completely, and no final conclusions can yet be announced. It appears that the gradient should be approximately unity (that is, luminance contrast, $\Delta B/B$, should be reproduced practically unchanged) in the central portion of the tonal scale.[11] In other portions of the tonal scale, the amount of the reduction of the gradient (and therefore of luminance contrast) that can be tolerated seems to be related inversely to the importance of such tones and contrasts in the picture.[15] These compressions are optimum in the sense that they make possible the best use of the characteristics of the printing paper, which are dominated by limited density scale and nonlinear characteristic curves of the photographic materials. The key idea in this discussion, the relative importance of contrasts in various portions of the tone scale, is as yet undefined. A suitable definition will have to be operational, in terms of how "importance" is to be evaluated, based on psychophysical studies of the results of judgments of scenes.

No definition of optimum quality, nor rule for evaluating particular reproductions, can be significant or useful, no matter how simple, unless it takes into account the ultimate limitations of the process and psychophysical correlations based on quality judgments of various compromises designed to get the most satisfactory reproductions within those limitations. The fundamental question is "What is the best that can be done under the circumstances?" Like the maximum luminous efficiency, Fig. 3, of sources and maximum luminous transmittances of filters, the answer to this problem will probably include a specification of how to get the best reproduction. That will necessarily specify some such tone reproduction curve as B in Fig. 9. To use any other curve, such as A or C, will result in poorer reproduction. The first will fail because it ignores the circumstance of limited luminance ratio of the paper (or screen, or television tube). The second will fail because it adopts too naive a compromise, excessively reducing important contrasts for the sake of equally prominent reproduction of unimportant contrasts. Finally, any realistic measure of the quality of reproduction will be based on the smallness of departures of slight contrasts from those of the "best" reproduction, rather than on departures of density (or Munsell value) from ideal or exact reproduction, such as was assumed by Judd, Plaza and Balcom.[1]

Like tone reproduction, chromaticity reproduction can be evaluated in terms of discrepancies from the norm. Again, two problems are involved: How to identify the norm, "the best that can be done under the circumstances"? How to measure discrepancies of any actual reproduction from the norm so as to yield a useful figure of merit?

Judd, Plaza and Balcom[1] assumed

that exact colorimetric reproduction was the norm, and measured the discrepancies in Munsell units of hue and chroma. Hue is the name for the characteristic of color sensation according to which red is most distinctively different from green. Munsell hue is a conventional pyschophysical evaluation of hue. Chroma refers to the characteristic which differentiates highly saturated or pure colors from colors of the same hue that are desaturated, for example, by dilution with white or gray. To a fair approximation, if chroma is constant, Munsell hue differences of one unit are equally noticeable, regardless of the particular hues. One unit of Munsell hue difference is approximately twice as noticeable at ten units of chroma as at five units of chroma, and others in proportion to chroma. The complete one-hundred-step hue scale at constant chroma can be represented by a circle, Fig. 10, and the chroma scales for various hues as radii from gray at the center. Since the metrics of this "color map" are approximately Euclidean, one hue step at ten units of chroma is only slightly more noticeable than one half a chroma step. However, Judd, Plaza and Balcom[1] considered hue errors about four times as objectionable as equally noticeable chroma errors. In their evaluation of the seriousness of chromaticity errors, therefore, they penalized various reproductions as much for unit errors of Munsell hue at chroma 10 as for two-unit chroma errors. They did not consider that errors in some hues, such as bluish-green and purples, are much less objectionable than equally noticeable errors of hues of human skin and other familiar materials.

Having weighted all the hue and chroma errors according to the principle described above, they averaged them. In effect, this implies that all equally satisfactory reproduction of the chromaticity, C, in Fig. 10 are represented by points on a diamond-shaped boundary,

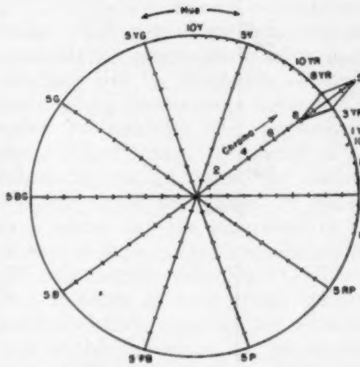

Fig. 10. Diagrammatic representation of Munsell hue circuit at 10 chroma, principal chroma scales and boundary of equally satisfactory reproductions of hue, YR; chroma, 10, according to formula of Judd, Plaza and Balcom.

such as shown on Fig. 10. It also implies that ten small errors are as serious as one error ten times their average, thus repudiating the conventional least-squares principle for minimizing errors. This procedure also ignores the common finding that errors all in one direction are less objectionable than equally great errors in diverse directions.

Series of color prints have been made from well-exposed color-separation negatives of several typical scenes. The prints of each of these series differ in tone reproduction, balance, and in other ways subject to controlled variation. These series have been presented to numerous judges, and their judgments have been compared with results of measurements of various colors in the prints. The various points in Fig. 11 represent the chromaticities of a spot on the forehead of a portrait of a young lady, as reproduced in a number of prints, which exhibit variations of balance from too red or yellow to too blue, and from too green to too pink. Sufficiently small steps of variation were used so as to obtain a number of

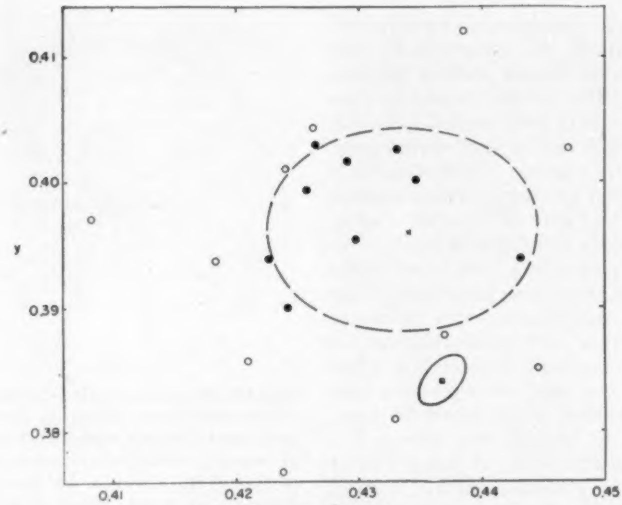

Fig. 11. Chromaticities of forehead of original subject (square), of best reproduction (cross), of reproductions accepted by 50% or more judges (solid dots) and of reproductions accepted by less than 50% of judges (open circles).

These chromaticities are based on the assumption of a 4000 K blackbody source of illumination. Broken curve indicates an estimate of the region of 50% or greater acceptance. The ellipse represents chromaticities just noticeably different from that of the subject's forehead.

satisfactory prints. These prints were submitted to a number of judges who were asked to accept or reject each on the basis of balance alone. The print accepted by the most judges (83%) had the forehead color shown by the cross. The solid dots represent the forehead colors in prints having 50% or greater acceptance, and the open circles show the forehead colors in prints accepted by less than half the observers.

The broken curve in Fig. 11 encloses the probable zone of 50% or greater acceptance. The square below this zone represents the actual color of the girl's forehead, and all points on the ellipse drawn around it represent colors all equally noticeably different from the actual skin color.

Two conclusions are indicated by the diagram in Fig. 11. First, optimum reproduction of skin color is not "exact" reproduction. The print represented by the point closest to the square ("exact reproduction") is rejected almost unanimously as "beefy." On the other hand, when the print of highest acceptance is masked and compared with the original subject, it seems quite pale.

In the second place, the shape of the 50% acceptance zone is similar to the shape of the zone of equally noticeable differences. This finding does not support the decision of Judd, Plaza and Balcom,[1] who assumed four times greater tolerance for chroma errors than for equally noticeable hue errors. Approximately horizontal radii of the 50% acceptance zone and of the equal-noticeability ellipse represent chroma

differences. Vertical radii indicate hue differences.

The discrepancy between "exact" reproduction and preferred reproduction is partly due to distortions inherent in the process, such that a certain discrepancy of a particular color is necessary to permit the best over-all reproduction of all colors in the picture. But, as discussed in the case of monochrome reproduction, it must also be due to differences of the conditions of observation, or of the observer and his attitudes when observing pictures and when observing real objects. Certainly, no such discrepancies should be introduced by a picture window in your living room, nor by a mirror in your dressing room. In such a case, we usually consider that we are looking at the "real thing." Perhaps the farther we get from that attitude, the greater the discrepancy becomes. Perhaps wishful thinking is partly responsible, with or without the acquiescence of fading memory. Certainly, differences of adaptation must play some part, but, for the ordinary range of adapting conditions when viewing scenes and pictures, this cannot account for more than a small fraction of the discrepancy shown in Fig. 11. Whatever the causes, the discrepancy is real, and is typical of the conditions under which photographic portraits are viewed. Since similar distortions and conditions of observation are customary with motion pictures and television, similar discrepancies are likely to be necessary for best results with those media. Face colors in 25 portraits of exhibition quality have been measured. Ten of these were made with the Kodak Flexichrome Process, in which every color is completely and separately under the control of the artist, so that no compromises are necessitated by chromatic distortions of the process. Three others were pastel portraits of children by two professional artists, and two were oil paintings by a prominent contemporary artist. The original subjects were not available for spectrophotometric measurement, but the foreheads of twelve more young people were measured, in order to establish the approximate range of face colors. The range of face colors in the portraits was entirely separate from the range of natural face colors, and the separation of the centers of those ranges is approximately the same as indicated in Fig. 11. Therefore, it seems to be not only quixotic but fallacious to assume exact reproduction to be the norm, or to measure degradations from that basis.

Similar results have been obtained with other colors. Figure 11 should not be regarded as anything other than indicative of the general nature of the results. The directions and amounts of difference between exact reproduction and optimum reproduction are different for every color tested. They must also be different, even for a single color, for processes with essentially different limitations and unavoidable distortions.

Although the 50% acceptance boundary has not exactly the same shape or orientation as the ellipse of equal noticeability in Fig. 11, assumption of such a similarity would be a fair first approximation, and use of this assumption for the general case is suggested until direct determinations are made of the 50% acceptance boundaries for other representative colors. Equal-noticeability ellipses found in a recent investigation[19] are shown in Fig. 12. Ellipses inferred from these have been specified for all locations in the chromaticity diagram by use of the three quantities, g_{11}, $2g_{12}$ and g_{22}, shown by the contour diagrams in Figs. 13 to 15.[20]

The equal-noticeability ellipse centered on any point, x, y, in the chromaticity diagram is defined by the equation

$$g_{11}\Delta x^2 + 2g_{12}\Delta x\Delta y + g_{22}\Delta y^2 = 1. \quad (1)$$

The angle, θ, which the major axis makes with the horizontal axis, is given by

$$\tan 2\theta = 2g_{12}/(g_{11} - g_{22}). \quad (2)$$

The value of 2θ is to be chosen from the first two quadrants (so as to make θ less than 90°) when $2g_{12}$ is negative. When $2g_{12}$ is positive, θ is greater than 90°, and therefore 2θ should be chosen from the third or fourth quadrants, depending on the sign of tan 2θ.

Half the length of the major axis of the equal-noticeability ellipse is given by

$$a = (g_{22} + g_{12}\cot\theta)^{-1/2}. \quad (3)$$

and half the length of the minor axis is given by

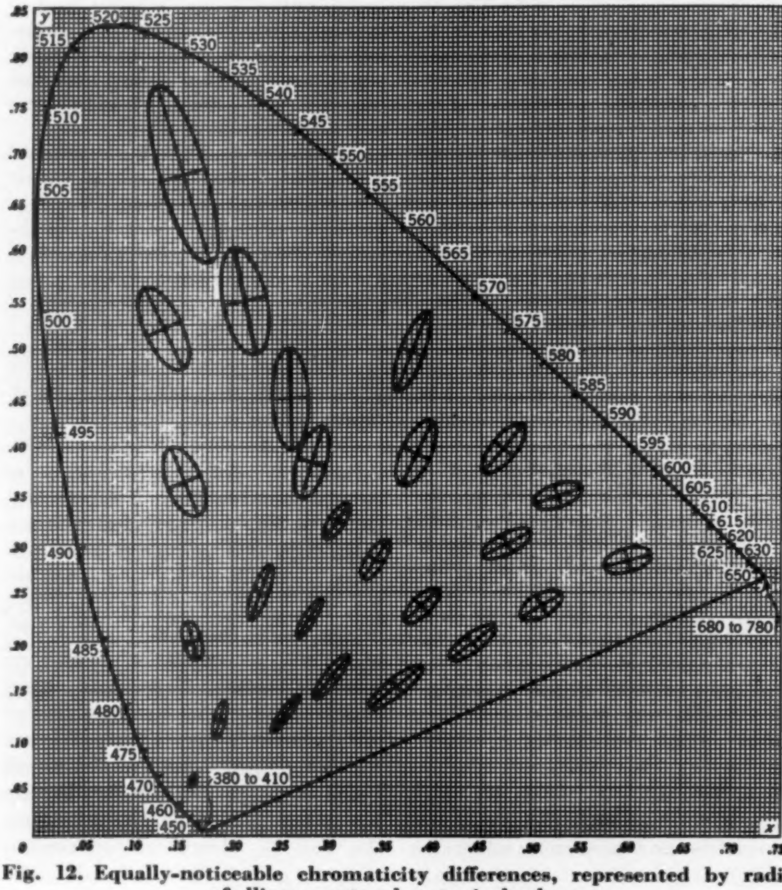

Fig. 12. Equally-noticeable chromaticity differences, represented by radii of ellipses centered on typical colors.

These radii are actually ten times the standard deviation of color matching in a certain colorimeter. Under favorable conditions, color differences equal to one tenth of these radii are just noticeably different.

$$b = (g_{11} - g_{12} \cot \theta)^{-1/2}. \quad (4)$$

Any chromaticity difference, Δx, Δy, that is likely to be encountered as an error in color reproduction by a reasonably satisfactory process may be specified as a multiple (e) of the arbitrary unit of equal noticeability represented by the ellipses in Figs. 11 and 12 by use of the formula

$$e = (g_{11}\Delta x^2 + 2g_{12}\Delta x\,\Delta y + g_{22}\Delta y^2)^{1/2}. \quad (5)$$

Silberstein[21] and MacAdam[16] have shown how to use such data are represented by Figs. 13 to 15, to compute the number of just-noticeably different chromaticities represented by any area of the chromaticity diagram. Symbolically, this number is proportional to the surface integral,

$$\int_s (g_{11}g_{22} - g_{12}^2)^{1/2}\, dx\, dy.$$

For the triangular gamut of the "C"

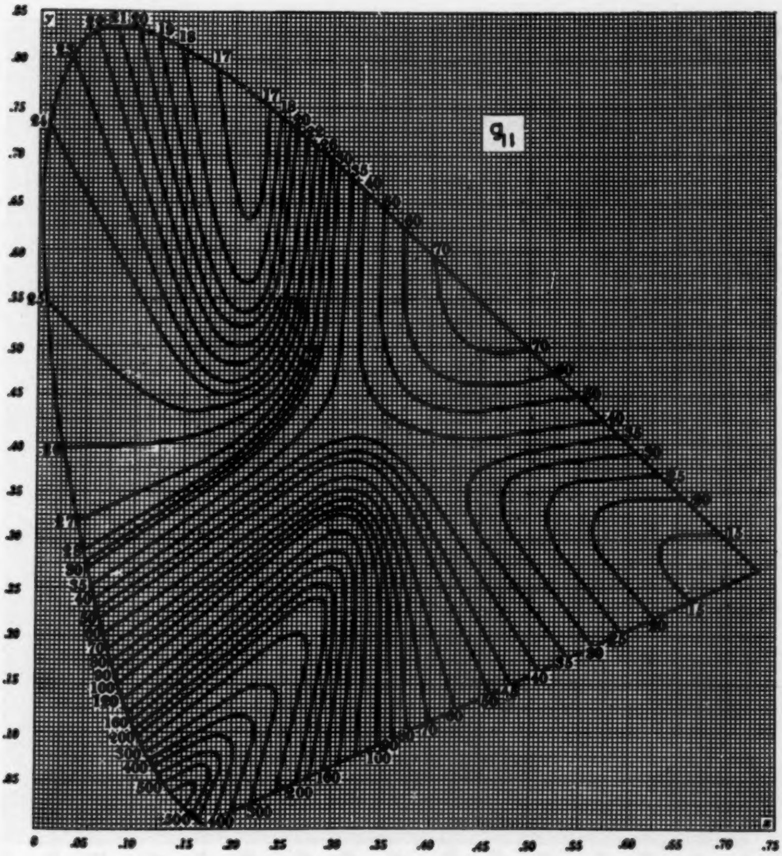

Fig. 13. Distribution of values of first metric coefficient in Formula (5) for noticeability of chromaticity differences. Numerical values shown should all be multiplied by 10^4.

set of primaries, shown in Fig. 4, the number of just-noticeably different chromaticities is about five thousand. For the "A" set, whose gamut is shown in Fig. 5, the number of just-noticeably different chromaticities is about three thousand. These numbers may be compared with seventeen thousand, an estimate of the total number of just-noticeably different chromaticities, up to and including spectrally pure colors.[16]

It is conceivable that some such formula as (5) may be useful for expressing results of the kind shown in Fig. 11. For this purpose, two modifications would be essential: first, to compute the deviations, Δx, Δy, from the geometric center of the 50% acceptance boundary and, second, to modify the values of the metric coefficients, g_{11}, $2g_{12}$, g_{22}, in accordance with the differences of size, shape and orientation of the acceptance boundary and the ellipse of equal noticeability.

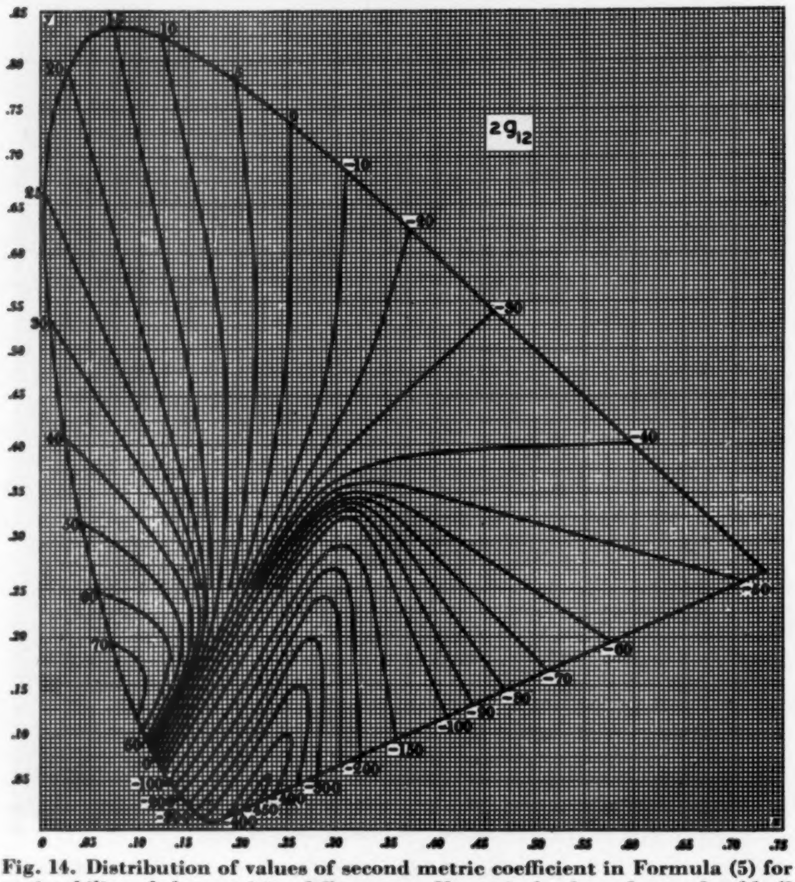

Fig. 14. Distribution of values of second metric coefficient in Formula (5) for noticeability of chromaticity differences. Numerical values shown should all be multiplied by 10^4.

The centers of the acceptance boundaries, and also their shapes, specified by g_{11}', $2g_{12}'$, g_{22}', may be expected to differ from process to process and for various classes of observing conditions. Thus, different kinds of distortions of the relations of reproduced colors, and various interactions of the production variables, such as the mutual interference of functions of the dyes in subtractive processes, mentioned previously, can be expected to result in different centers and shapes of the acceptance boundaries. Similarly, various angular subtenses of the picture from the point of view of the observer, and various distributions of light in the surroundings can be expected to call for variations of the centers and the shapes of the acceptance boundaries. Such must also result from various types of interest, for example: casual, as in the case of variety shows; or intent on details, such as the color of the

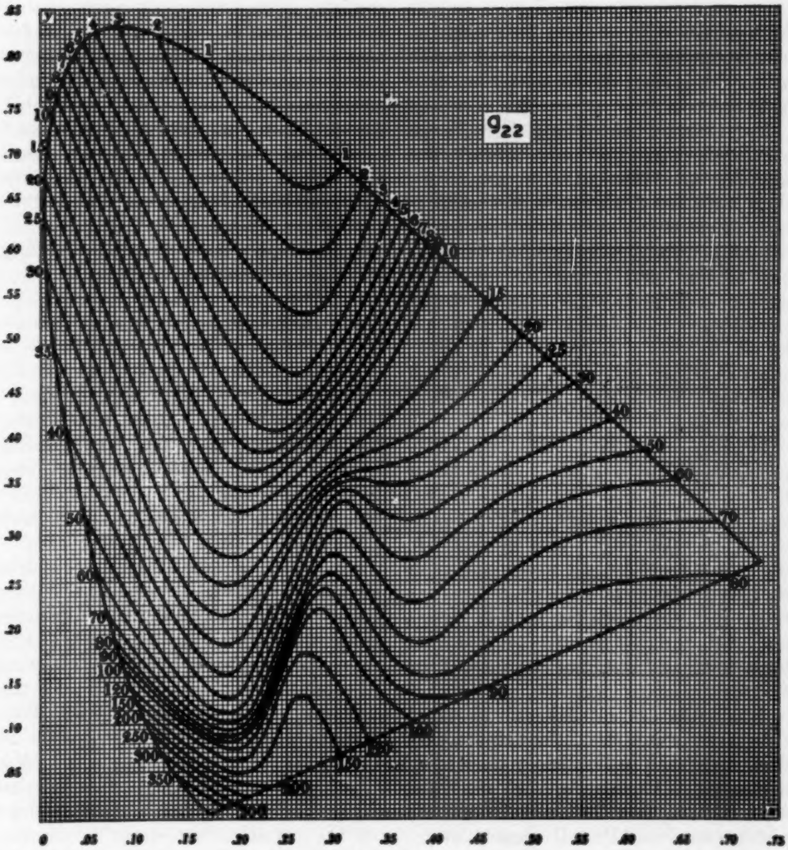

Fig. 15. Distribution of values of third metric coefficient in Formula (5) for noticeability of chromaticity differences. Numerical values shown should all be multiplied by 10^4.

shirt of a jockey in a horse race; or professional, such as close-ups of surgery.

It is conceivable that results of statistical studies of the reproductions of a number of colors can be combined by use of terms of this form. The root-mean-square error of reproduction might, for example, be computed by

$$E = \left[\sum_{i=1}^{i=n} (g_{11}'\,\Delta x^2 + 2g_{12}'\,\Delta x\,\Delta y + g_{22}'\,\Delta y^2)i/n\right]^{1/2}. \quad (6)$$

Adjustment of a process to reduce E to the smallest value employs the customary principle of least-squares adjustment.

In order to use such a formula to obtain a figure of merit for chromaticity reproduction, the optimum reproductions (that is, the centers of the 50% acceptance boundaries) will have to be determined for a number of colors that are typical and important in color pictures. The sizes and shapes of the acceptance boundaries will also be found during that psychophysical analysis, thus indicating the required modifications, g_{11}', $2g_{12}'$, g_{22}', of the metric coefficients.

Having considered the separated problems of how to evaluate departures from optimum tone reproduction and how to evaluate departures from optimum chromaticity reproduction, it remains to consider how we can combine such results so as to evaluate departures from optimum color reproduction, which almost invariably consist of errors of both tone and chromaticity reproduction.

Judd, Plaza and Balcom[1] assumed that such errors could be weighted by their relative importance and simply averaged. They decided that one Munsell value step is as important in a color picture as two Munsell chroma steps, and they assigned relative weights to discrepancies from "exact" tone and chromaticity reproduction in accordance with that conclusion. Analogous to the case of the simple addition of weighted hue and chroma "errors," this implies that an octahedral surface, having three diamond-shaped principal cross-sections in the hue-chroma, hue-value and chroma-value planes, represents all equally objectionable reproductions of a single color in the original scene.

No attempt has yet been made to combine results from the psychophysical studies of tone reproduction and chromaticity reproduction. It is conceivable that the kind of formula suggested for statistical ratings of chromaticity reproductions can be generalized, analogously to the way in which the original formula for the noticeability of equiluminous chromaticity differences has been generalized to measure the noticeability of combined luminance and chromaticity differences.[22] The latter extension was accomplished by adding three terms to the simpler formula

$$e = (g_{11}\,\Delta x^2 \pm 2g_{12}\,\Delta x\,\Delta y + g_{22}\,\Delta y^2 + 2g_{23}\,\Delta y\,\Delta \log B + g_{33}(\Delta \log B)^2 + 2g_{13}\,\Delta x\,\Delta \log B)^{1/2}. \quad (7)$$

The values of $g_{11}, \ldots, g_{13}$ suitable for the measurement of the noticeability of color differences were published for a large number of typical colors.[22] No interpolation procedure has yet been published.

Since tone reproduction studies have shown that contrast reductions, rather than "errors" of luminance, are significant, the use of a measure of this reduction in place of $\Delta \log B$ may be more appropriate in a formula for the figure of merit of color reproduction. Luminous contrast reduction might be measured by $1 - (\Delta B_r/B_r)/(\Delta B_o/B_o)$. To a good approximation, this is equal to $1 - \Delta \log B_r/\Delta \log B_o$. If the slope of the reproduction curve is denoted by M_r, then $1 - M_r$ represents the same approximation to the expression for luminous contrast reduction. This

quantity has been studied by Jones, as the most promising measure of loss of tone reproduction.[23] If we adopt the symbol, $\Delta M = 1 - M_r$, then a conceivable formula with which to measure a particular error of color reproduction is

$$e' = (g_{11}'\,\Delta x^2 + 2g_{12}'\,\Delta x\,\Delta y + g_{22}'\,\Delta y^2 + 2g_{23}'\,\Delta y\,\Delta M + g_{33}'\,\Delta M^2 + 2g_{13}'\,\Delta x\,\Delta M)^{1/2}. \quad (8)$$

The g's in this formula may be expected to differ from those in the formula for the noticeability of color differences, because of the replacement of $\Delta \log B$ by ΔM and because the 50% acceptance boundary in the chromaticity diagram (Fig. 11) is different from the ellipse of equal noticeability. It should also be noted again that Δx and Δy should be measured from the optimum reproduction, such as indicated in Fig. 11, rather than from the chromaticity of the original. It is also to be noted that the relative magnitudes of the coefficients in the first and last groups of three terms in Eq. (7) depend very much on the conditions of observation. For instance, the ratio of g_{33} to g_{11} is fifty thousand times as great when the observers' task is to read small letters that differ only slightly in color from their background, than when they are asked to rate various attempted "matches" presented in the form of uniform and nearly gray color-prints, 3 × 4 in. large, mounted on white cards with unremovable, inch-wide borders. This factor is the square of the ratio (225) of the luminance contrasts equivalent to a prescribed chromatic contrast under the two circumstances.[24]

When a number of reproduction errors are to be averaged, it will probably be necessary to weight them according to their importance. To some extent, these weights will depend upon the subject matter of each picture. The color of human skin will frequently be weighted heavily and other colors in accordance with their familiarity, emotional associations and frequency of their occurrence. Furthermore, those weights should probably depend upon the luminances of the colors, relative to the tonal range of the scene. Certainly, optimum rendering of the chromaticity as well as the luminance of the face of a person in the deeply shadowed background of a scene is less important than for the face of a person in the brightly lighted foreground. It therefore seems probable that the "importance" factors, which were first suggested in the discussion of optimum tone reproduction, should be applied not only to the terms expressive of luminous contrast reproduction, but to all terms alike. For this reason, it was suggested that it is probably inadvisable to subdivide the problem of specifying quality of color reproduction into two parts, dealing separately with tone reproduction and chromaticity reproduction.

If all these conjectures are combined, a general form can be suggested for the root-mean-square error of color reproduction:

$$E = \left[\sum_{i=1}^{i=n} W_i(g_{11}'\,\Delta x^2 + 2g_{12}'\,\Delta x\,\Delta y + g_{22}'\,\Delta y^2 + 2g_{23}'\,\Delta y\,\Delta M + g_{33}'\,\Delta M^2 + 2g_{13}'\,\Delta x\,\Delta M)_i/n\right]^{1/2}. \quad (9)$$

For this evaluation, Δx and Δy should be measured from the optimum reproduction. The contrast reduction term

$$\Delta M = 1 - \Delta \log B_r/\Delta \log B_o$$

is primarily a function of B_r. Any residual dependence of ΔM on x, y is an indication of unstable balance of the system, although not necessarily a suitable measure of balance.

Judging from analogous data on noticeability of color differences, g_{11}', ..., g_{13}' depend primarily on chromaticity for all comfortable reading levels of luminance (above about one foot-Lambert). The weights, W_i, which could be combined with g_{11}', ..., g_{13}', require separate investigation and will

probably vary most markedly with luminance, B_r.

A "figure of merit" for color reproduction can be derived only by adoption of some arbitrary convention. If g_{11}', ..., g_{13}' are based on the 50% acceptance boundary, as in Fig. 11, then an average error, E, equal to 1 means that the picture would be rejected by 50% of the judges. To a first approximation, the percentage of judges who would reject a reproduction having some other value of E would be proportional to the ordinate of the probability integral, in which the usually tabulated abscissa, hx, is 0.477 E. Thus, for $E = 2$, $hx = 0.954$, and it is to be expected that the reproduction would be rejected by about 82% of the judges. For $E = 0.5$, it may be expected to be rejected by about 26%. This direct interpretation of E is lost if a figure of merit of the form, $100(1 - E/C)$, suggested by Judd, Plaza and Balcom[1] is adopted, C being some arbitrary constant, such as 30, in the instance cited. If a figure of merit is desired, which shall be high for the most satisfactory reproductions, and low but never negative for the worst reproductions, perhaps the percentage of judges accepting the reproduction will serve. Thus, from these examples, the figure of merit corresponding to $E = 1$ would be $F = 50$; for $E = 2$, F would be 18; and for $E = 0.5$, $F = 74$. For other values of E, F can be computed easily by use of any table of the probability integral.

Such an interpretation makes it evident that figures of merit cannot be combined so as to predict the quality of reproduction of a two-stage process, such as copying or televising a color photograph. The errors of reproduction of each process are vectors, which may compensate each other as well as accumulate. Furthermore, the errors are not measured from an absolute base, but from subjectively optimum reproductions. For these and many other reasons, it seems futile to hope for a figure of merit which can be multiplied, or combined in any way, to predict the quality of reproduction of combined processes. The figure of merit of a combined process can be determined only by application of the principles, and probably by use of the same formula as for direct reproduction.

Retrospect and Prospect

The evaluation of quality of color reproduction poses many complex problems. The order in which they have been investigated is an historical accident, arising from the fact that black-and-white pictures were made first and were important long before color photographs. The additional complexity of the latter, not only the complexity of their production but the complexity of their appearance, further delayed investigations aimed at evaluating their quality.

It is by no means certain that results of tone reproduction studies of black-and-white pictures can be carried over, and merely supplemented by studies of chromaticity reproduction. Optimum reproduction needs to be identified. Since it depends upon the limitations of the reproduction process, as well as upon human vision and judgment, optimum reproduction will probably have to be determined for each process separately.

Projected photographic transparencies share many, but not all, of the limitations of television. To the extent to which their limitations are equivalent, results for one process can probably be applied to the other. Prints on paper suffer from much more severe limitations. Only the principles of investigation, not specific results, can be expected to apply to motion pictures and to television. Most of the tone reproduction studies have been made on reflection prints, and investigations of quality of color photographs are almost entirely concerned with re-

flection prints. Perhaps this is because the limitations of paper prints are so serious. Every effort has to be made to get the best results possible under the circumstances. However, it is only a matter of time before the limitations inherent in motion pictures and in television force more systematic studies of reproduction quality. For this reason, this account is given of the principles of investigation which have been used in tone reproduction studies of black-and-white prints, and of the way in which the method seems to be applicable to color photography.

This program may seem elaborate, but it does not seem wise to base important decisions on less direct evidence. The investigation of color quality may be expected to be easier, quicker, more systematic and complete in color television than in color photography, because changes in production variables can be made more easily, with continuous gradations if desirable, and reproducibly, by electronic controls. Different pictures have to be made for color photography, and photographic processing controls are less direct, less convenient to change and less reproducible than electronic controls. Each desired change requires a long time in color photography, whereas most changes could be made subject to nearly instantaneous control in color television. The variety of tone reproduction curves (transfer curves) obtainable with television should be much greater than in photography, and a more complete and systematic search for the optimum quality of color reproduction should be possible.

The program is to vary the production controls in systematic manners, measure the resulting color reproduction in the best way known (e.g., the ICI method at the present time), submit the reproductions to visual judgment, and study the judgment data in comparison with the measurements in order to find significant correlations. The growing experience of such studies of color photography is suggested as a guide. Particular studies should be made of skin colors, gray scales and other crucial colors. If certain conditions seem to be identified as giving optimum reproduction, it would be very desirable to set them up and verify the fact, or to find exceptions which can be used to improve the concept of optimum. Deviations of measured characteristics of other reproductions should then be computed, or directly measured, from the optimum. Quality ratings, either directly reported by judges or based on the proportion of judges who accept the reproduction as satisfactory, can then be correlated with the deviations from optimum reproduction. Only in this general fashion can we establish a method for assessing various kinds of deviations and their combinations.

Preliminary estimates of optimum reproduction and of seriousness of deviations may be based tentatively on results of studies of noticeability of color differences and on fragmentary results of studies of color photography. These estimates can be improved as various parts of the program are carried out. This beginning offers a basis for growth. New results can be grafted on these roots.

The formulas shown in this account are extremely tentative. They are merely suggestive of the nature of the problem, and of conceivable forms of the solution. These may prove unnecessarily complex. They are sufficiently definite in form to guide research, and yet they are sufficiently flexible so that their accuracy can be improved with each increase of our knowledge. In this sense they symbolize a program of research, and a goal.

One conclusion, only, can be stated with assurance, that the successful index of quality of color reproduction will ultimately be established as a result of psychophysical analysis of

judgments of picture quality, referred unambiguously to the pictures by measurements of relevant optical quantities.

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A Time-Motion Study by Methods of High-Speed Cinematography

By Henry W. Baer, Bernard F. Cohlan and Arthur R. Gold

In this paper an attempt has been made to evaluate a method of motion study pertaining to moving machinery. The test object was a 13-ton capacity punch press and the motion study was performed with a high-speed motion picture camera. It is shown that the motion picture camera produces: (1) a visual indication of the actual occurrence which allows an understanding that nonvisual means could not afford; (2) a method of study which does not influence the system studied in the least; and (3) a record of the occurrence which has very little inherent error.

The advent of high-speed cinematography places a valuable tool in the hands of the research worker. Motion picture photography has already proved itself in many phases of science, but in some cases it is necessary to test its applicability and determine the error in the resulting record.

A common method of investigation of moving machinery has been the use of recording devices such as strain gage bridges, oscillographs, photoelectric cells, and others. In this investigation an attempt has been made to determine the merits of data obtained from a high-speed motion picture camera.

All tests were conducted in one of the Engineering Research Laboratories of the University of California, Los Angeles campus. The research was conducted by the writers who were under the general direction of Professor D. Rosenthal, and with technical advice of Mr. A. Keller for the use of high-speed photographic equipment.

Description of Equipment

A standard 13-ton capacity punch press was chosen as a typical example of moving machinery. As a result of a previous investigation,* it was possible to operate the press near its full capacity. The load simulator consisted of a steel, cone-shaped indentor penetrating an aluminum block. Aluminum was chosen to reduce wear on the indentor, thus eliminating a variable due to changes in indentor form. The punch

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* The previous investigation consisted of a thorough stress analysis of the entire punch-press structure to determine the maximum allowable load for continuous operation.

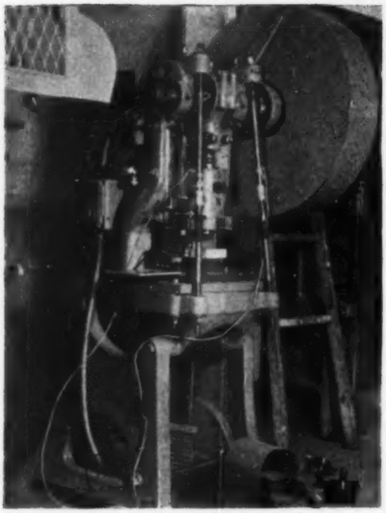

Fig. 1. Punch press.

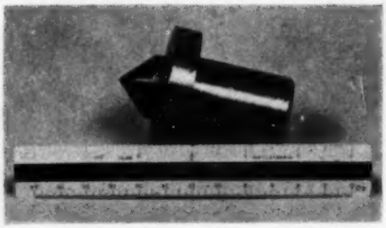

Fig. 2. Load simulator.

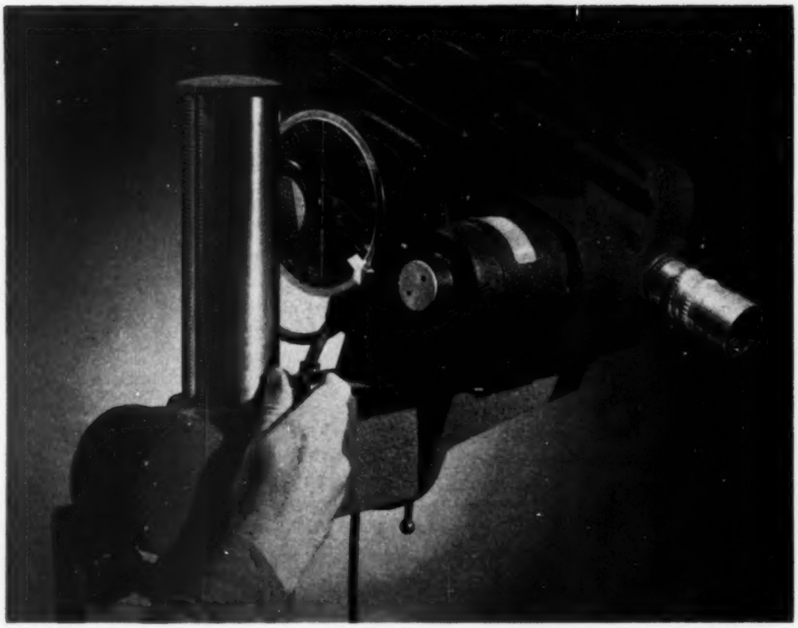

Fig. 3. Kodak High-Speed Camera.

press and load simulator are shown in Figs. 1 and 2.

The photographic measurements were obtained by a Kodak High-Speed Camera (see Fig. 3). This camera uses 16-mm film and has a maximum speed of 3000 frames/sec. The lens used was of 2½-inch focal length.

Only ram displacements were recorded. A pointer attached to the ram was photographed against a stationary scale along with a small clock marking time (Fig. 4). The clock was calibrated in milliseconds which proved to be of sufficient sensitivity for the purpose. High-speed motion pictures of the pointer, the scale, and the clock were taken while the press was in motion.

The force exerted by the ram was determined by an inked stylus oscillograph with a null-type strain gage bridge input. This force was determined from the elastic strain induced in the press tie rods (Fig. 1). To this end a pair of electric strain gages was mounted on each tie rod (Fig. 5). The strain gages in each pair were connected in series to eliminate the effect of accidental bending. The record of force was calibrated by loading the ram statically. This calibration of force was considered as an approximation only since the actual loads were dynamic ones. The time constant of the oscillograph was such that only the average value of force could be measured with reasonable accu-

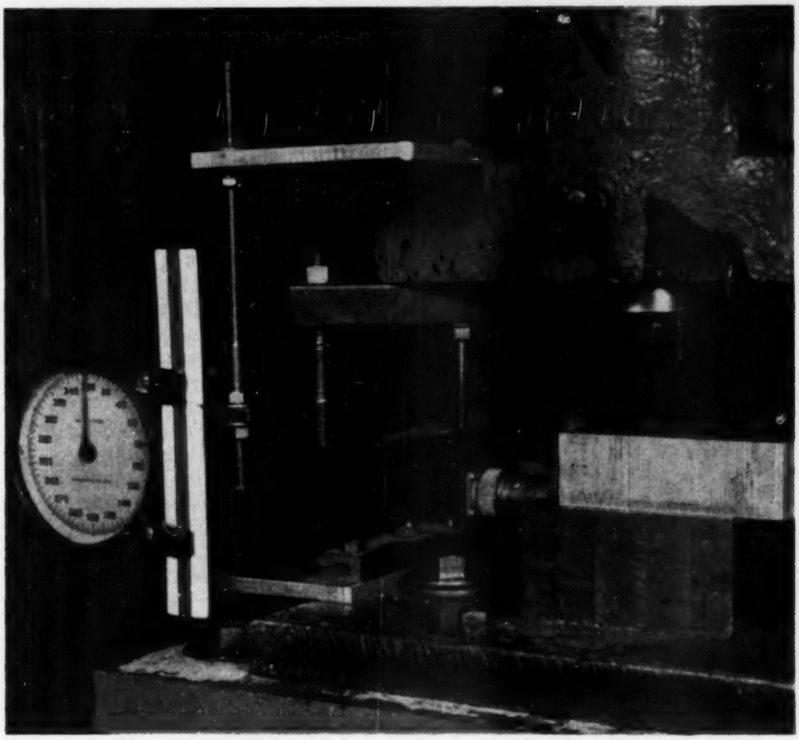

Fig. 4. Ram, pointer, stationary scale and clock.

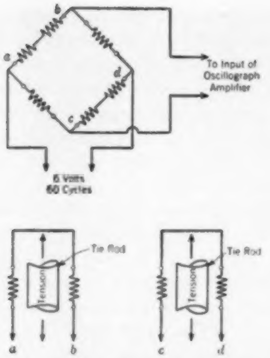

Fig. 5. Schematic arrangement of electric strain gages.

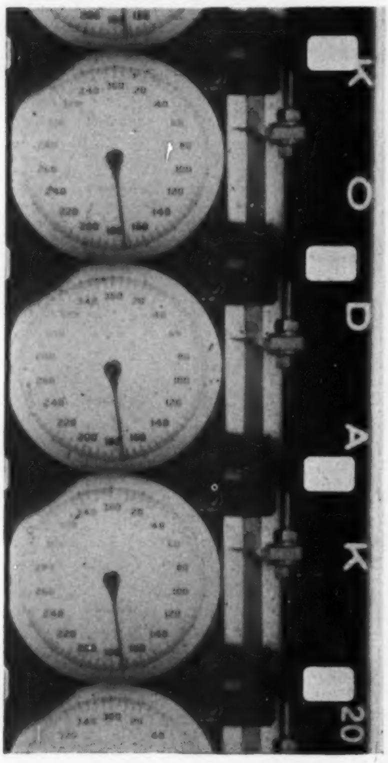

Fig. 6. Section of recording film (×4).

racy; therefore, the force indication was used only as a guide to operation within the capacity of the press.

Experimental Procedure

Experimental data were obtained from photographic recordings of the press operation. The operation consisted of repeated impacts between the indentor and the aluminum specimen, simulating an actual punch-press operation. The resulting films were translated into ram displacement vs. time curves to facilitate study.

These data were reduced by taking readings of time and displacement from the film (see Fig. 6) by means of a low-power binocular microscope. The maximum error incurred in the time measurement was estimated to be 1 msec (millisecond) and the maximum error in the displacement measurement was estimated to be 0.005 in. The reduced photographic data are shown in Fig. 7. Two curves are shown, one for load, and one for no-load motion of the ram.

Experimental Results

The no-load curve is essentially a cosine curve with an amplitude of 1.25 in. and a period of 460 msec. The load curve departs from a cosine curve during impact and after impact it returns to a cosine curve as the flywheel returns to no-load energy conditions. The displacement amplitude due to this load is 1.19 in. and its period is 480 msec. The difference of 0.06 in. in amplitude between load and no-load curves can be attributed to clearance between press components which manifests itself as backlash. The load curve indicates that the ram came to rest upon impact and remained at rest until the backlash was taken up. Upon absorption of the backlash the indentor was driven into the specimen. This portion of the stroke actually did the plastic and elastic work. At completion of the work interval the ram force was removed and the

stored elastic energy raised the ram. Here again the ram remained stationary during the absorption of the backlash and then accelerated to a normal energy condition with respect to its position.

Analysis of Results

The value of a photographic analysis of this type can be demonstrated in two ways: (1) by a comparison of the experimental findings with the expected theoretical performance; and (2) by the detection of occurrences that would not ordinarily be expected from theoretical considerations. In accordance with the first principle the following theoretical discussion will indicate a good correlation between the experiment and theory.

Since it is reasonable to assume backlash in the driving mechanism—and a simple calculation reveals that the indentor velocity is relatively small when impact occurs—, it can readily be seen that little work can be done until all backlash has been taken up. Therefore, it is reasonable to believe that the indentor comes to rest for a short period of time, while the backlash is absorbed. At the end of this time further penetration occurs until the limit of the stroke has been reached. Before the ram can again be lifted the backlash must once more be taken up. During this time the indented metal gives up its elastic energy to the ram, thus lifting it a short distance. Here again the ram remains at rest while the backlash is absorbed. At this point the ram undergoes motion which does not seem consistent with the predicted path indicated by the no-load curve. This is an occurrence which was not predicted from theory and which indicates the sensitivity of the method. At first thought it would seem that the ram could not be lifted until a time later than that indicated by the no-load curve for the same displacement. The subsequent discussion appears to substantiate the experimental findings just described.

During the impact of the ram with the specimen the flywheel and motor speed greatly decrease. Consideration of the torque-speed characteristics (Fig. 8) of an induction motor shows that slightly decreased speed is associated with a

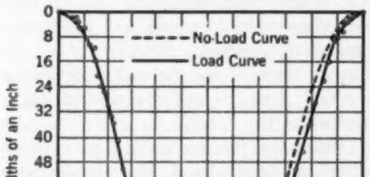

Fig. 7. Displacement-time curves.

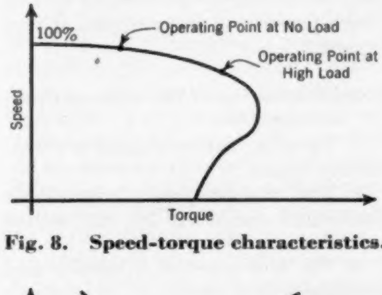

Fig. 8. Speed-torque characteristics.

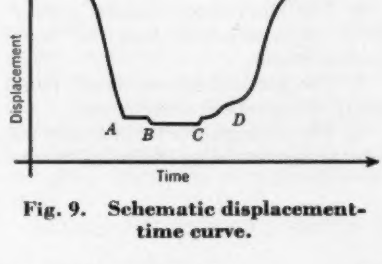

Fig. 9. Schematic displacement-time curve.

highly increased torque. Since in induction motors the assumption is made that the torque is proportional to the current, it seems reasonable that a torque requirement change will cause a current change. This shows that during impact a current surge occurs.

Examination of Fig. 9 shows that the flywheel and motor see no load from points A to B and a large load from points B to C. During the period A–B the motor tends toward zero slip and during period B–C the slip increases to some large value. This change in speed and torque causes a large surge of current which tends to continue into the period C–D due to the inductive properties of the motor. This surge current could accelerate the driving system to a point where it could lift the ram at an earlier time than that indicated by the no-load curve. Under this high acceleration the flywheel would return to a normal energy level in an extremely short time after impact, as was actually indicated by the experiment.

Thus the high-speed camera has shown an occurrence that could have been overlooked by a recording system which possesses a lesser degree of perception.

Final Evaluation of High-Speed Cinematography

1. Versatile; can be adapted to a wide variety of uses.

2. The photographic equipment is stable and unaffected by surrounding conditions.

3. The film provides a reliable and permanent data record.

4. The equipment requires a minimum of installation time for time-motion studies.

5. The method allows direct visual study of high-speed occurrences.

6. The photographic method does not alter the system being studied as the system is completely isolated from the recording device.

7. The error introduced in translation from the film to the reduced form is negligible in most applications.

8. The ability of the photographic method to detect rapid changes is limited predominantly by the maximum camera speed. Its ability to detect small magnitude changes is limited primarily by the magnifying and resolving power of the lens and also by the grain size of the film. These limits far exceed the limits of other recording systems of comparable cost and complexity.

9. The photographic method has a disadvantage in that the experimental record cannot be used until the film has been processed which means delay and increased research cost.

Recommended Further Studies

In subsequent studies of the problem an attempt should be made to use high-speed cinematography in the determination of the following factors related to a punch-press operation:

1. What are the energy-time relations between flywheel and ram under several kinds of simulated loads?

2. What percentage of its kinetic energy does the flywheel lose during the interval of maximum work?

3. Is there a lag between minimum flywheel energy and maximum force exerted on the ram?

The above factors should be investigated by high-speed cinematography methods by establishing relationships of time functions of displacement, force, and flywheel revolution rates. It is hoped that a satisfactory answer to the above additional questions in conjunction with the data as presented in this paper could serve as a guide in future punch-press design. The recommended experiments would also demonstrate the utility of high-speed cinematography.

16-Mm Film Maintenance Cost and Analysis of Damages

By Ernest Tiemann and Dencil Rich

In the first part of the study, the maintenance costs of 192 prints of sound motion picture films in active circulation between 1942 and 1950 are analyzed. In the second part, an attempt is made to analyze the damages to motion pictures distributed during the course of one year of operation. Circulation figures and percentages for each month of the year are compared with the amount and percentages of damages occurring during the same period.

16-Mm Film Maintenance Costs

Increased use of the 16-mm film has brought into existence hundreds of new film libraries. Those responsible for the maintenance and supervision of these libraries are extremely interested in the maintenance costs of 16-mm films over an extended period of time. At institutes, conferences, and workshops, the question often arises: "How much does it cost to maintain a 16-mm film in a satisfactory condition over a period of from five to ten years?" An answer to this problem also makes it possible to plan amortization schedules including the original cost and maintenance expenditures.

The Audio-Visual Center of Indiana University has maintained an accurate inspection record of all films accessioned after July 1, 1942. Recently it was decided to make a study of all prints of films purchased during the fiscal year of July 1, 1942, to June 30, 1943, to determine the maintenance costs of all those prints that were still in active use. Of the 282 prints purchased during the period between July 1, 1942, and June 30, 1943, 192 prints were in continuous circulation till July 1, 1950. Accessioning, print control, inspection and booking cards were studied and analyzed for each of the 192 prints. By checking the bookkeeping records for each of the 192 prints, it was found that they were used a total of 18,149 days for an average of 94.5 days per print.

Eighty-three of the 192 prints were damaged to the extent that replacement footage was needed. One hundred and ten different replacement parts were added, requiring a total of 5,264 ft of replacement film. All of the films except one were black-and-white. The cost of replacement parts amounted to $476.36; the average cost of replacement footage per print amounted to approximately $2.50.

Although this preliminary study is in

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no way conclusive, it does indicate that for this particular group of prints, maintenance costs for replacement footage alone amounted to approximately $2.50 a print over a seven-year period. It is assumed that replacement costs will vary, depending upon these variable factors: (a) the number of bookings per print, (b) standards of maintenance, (c) comparative number of black-and-white and color prints, and (d) the cost of replacement footage.

Analysis of 16-Mm Film Damages

One of the most important factors influencing the maintenance costs of 16-mm films is the care given the films during the period when they are used by the customer. Each film library has a responsibility of keeping its prints in the best possible condition. To do this requires a systematic inspection of each print each time after it has been projected.

As a result of years of experience in inspecting films, the Audio-Visual Center of Indiana University has developed a very detailed classification of film damage which is consistently used in making an analysis of all types of film damages. Each inspector has the responsibility of preparing a report of each film damage, and periodically these reports are carefully studied and analyzed.

Recently a detailed study was made of all film damages that occurred during a full year of operation. As the result of this analysis, it was possible to study the factors which brought about the film damage and to chart a course of action in attempting to decrease future damages.

Table I. Damage Types.

Code No.	Description
1.	Chipped sprocket holes
2.	Teeth marks between sprocket holes, tears into frame
3.	Teeth marks on sound track
4.	Chipped sprocket holes, tears into frame
5.	Teeth marks between sprocket holes
6.	Chipped sprocket holes, single breaks to edge of film
7.	Teeth marks between sprocket holes, single breaks to edge of film
8.	Chipped sprocket holes, teeth marks between sprocket holes
9.	Nicks on frame side of sprocket holes
10.	Teeth marks in frame
11.	Tears into frame from sprocket holes
12.	Teeth marks in frame and on sound track
13.	Chipped sprocket holes, nicks on frame side of sprocket holes
14.	Chipped sprocket holes, teeth marks in frame
15.	Chipped sprocket holes, pleats across frame
16.	Missing footage
17.	Teeth marks between sprocket holes and on frame
18.	Claw marks between sprocket holes
19.	Film broken across frame in many places
20.	Pleats across frame
21.	Single breaks from sprocket holes to edge of film
22.	Chipped sprocket holes, teeth marks on frame and between sprocket holes
23.	Buckled film
24.	Breaks from sprocket holes toward edge and toward frame
25.	Sprocket hole edge of film snagged at intervals
26.	Nicked in outside corners of sprocket holes
27.	Edges of film pinched
28.	Sprocket hole edge of film shaved off

Methods of Procedure

As a basis for this study, a complete file of damage reports for a full fiscal year was consulted. Separating total from partial damages, the reports were broken down into months and the four sizes of films involved. All the damages for each month were tabulated in a systematic manner, indicating color of the film, amount and location of damage, and the type of damage.

The authors are in the fortunate position personally to have seen and passed judgment on all damages; hence, the descriptions are reasonably uniform.

After all damages were classified according to the descriptions given, each damage type was assigned a code number for ease in handling data. It may be added here that the damage types described in this paper are the major types found.

Results

In Table I are descriptions of the damage types in partial and complete film damages for a full fiscal year. Doubtless, there may be other types of rare damages found in former years, but in the main, this list of 28 damage types adequately describes damaged conditions of the group of films in question. Inasmuch as these damages are given code numbers, it may become necessary to use Table I as a reference point whenever damage-type code numbers alone are used in the discussion.

In Table II is a detailed breakdown of the frequency of damages found in 400-ft films. An analysis of partial damages found at the beginning of films shows that, with the exception of damage types 12, 13, 14, 19, 21, 24 and 25, all other damage types are represented. The total amount of black-and-white film damage amounted to 2,863 ft, whereas 814 ft of color film was damaged. Of the total number of damages found in the beginning of 400-ft films, 23% were in color films. Twenty-two per cent of the total damaged footage was color. Were it not for the high destructiveness of damage type 5, the damaged footage for color film would have been very much less, for in other damage types the average color film damage was usually less than for black-and-white films, which accounted for 40% of the 96 damages at the beginning of 400-ft films.

Table II continues with a detailed analysis of damages found in 400-ft films at various points up to the halfway mark in the film and some distance in from the beginning of the film title. Of black-and-white film, 1,195 ft were damaged, with 258 ft of color film damaged. Of the 80 damages, 22.5% were found in color film. Nineteen per cent of the total damaged footage was color film.

In the portion of the 400-ft film beginning at the halfway point, but not extending to the end of the film, 33 damages were recorded. Table II shows only one of these to be in a color film, with 13 ft, whereas there was a total of 679 ft of damaged black-and-white film.

At the extreme end of 400-ft films, as indicated in Table II a total of 58 partial damages was found. Of the total, 18 were color film damages, or 31% of the total number of the damages. For black-and-white film, 1,225 ft were damaged, with 589 ft of damaged color film or 32.4% of the total damaged footage. Twice as much black-and-white footage was damaged as color film footage.

For 800-ft films, starting at the beginning of film, Table III shows a total of 30 damages, of which 20% or 6 were damages in color films. In black-and-white films, 877 ft was damaged, with 306 ft damaged in color films. This indicates that 25.7% of the damaged footage was in color film. Of the total, black-and-white damaged footage amounted to 2.5 times that of color in 800-ft films, at the beginning of the film.

Table III shows a total of 26 damages in 800-ft films, occurring in that part of the film between the beginning of the

title up to the midpoint of the film. Damage types 6 and 8 were prominent, with 9 damages recorded under damage type 1. Only two damages of color film with a total of 306 ft were recorded. Twenty-four black-and-white films were damaged with a total footage of 411 ft. A high 43% of the total damaged footage was in color film, whereas only 8% of the damages were color films.

In the 800-ft film, from the midpoint on, but not extending to the end, 9 damages were located, 2 of which, or 22%, were in color films. Table III points out that 71 ft of the damage were black-and-white, with 74 ft in color film. Here is again an instance where the destruction of color film seemed to be out of proportion to what one might expect.

Damages at the end of 800-ft films were found to be limited, with two damages of black-and-white films and a total of only 27 ft involved.

One may readily see in Table IV that partial damages in 1,200-ft color film were indeed rare. Comparing only black-and-white in the four portions of the film, we see that there were a total of 5 damages, or 153 ft, at the beginning of the film. A considerable increase is shown in the portion of the film up to

Table II. Analysis of Partial Damages in 400-Ft Films

Damage Code No.	Total No. of prints	Average footage per damage	Point at which damage starts
Beginning of Film			
1 B-W*	39	31	
1 C	7	21	
2 B-W	1	21	
3 B-W	1	67	
4 B-W	2	112	
5 B-W	5	23	
5 C	4	126	
6 B-W	3	48	
6 C	4	14	
7 B-W	2	20	
7 C	1	21	
8 B-W	7	60	
8 C	1	6	
9 B-W	2	44	
10 B-W	3	20	
10 C	1	24	
11 B-W	2	26	
11 C	1	14	
15 B-W	1	50	
16 B-W	1	5	
16 C	2	6	
17 B-W	1	135	
18 B-W	1	18	
20 C	1	30	
22 B-W	1	85	
23 B-W	1	65	
26 B-W	1	61	
First 200 Ft			
1 B-W	43	20	56
1 C	8	10	99
3 C	1	4	94
4 B-W	1	6	87
5 B-W	5	8	79
5 C	4	18	73
6 C	1	18	21
8 B-W	4	26	89
8 C	2	28	52
9 C	1	24	168
10 B-W	2	76	8
12 B-W	1	6	18
17 B-W	1	8	124
19 B-W	1	9	6
14 B-W	2	10	23
Last 200 Ft			
1 B-W	18	19	309
1 C	1	13	202
4 B-W	1	12	356
5 B-W	1	3	376
6 B-W	3	12	318
8 B-W	6	39	294
13 B-W	1	17	252
20 C	1	4	223
22 B-W	1	8	218
25 B-W	1	126	224
End of Film			
1 B-W	25	31	
1 C	15	28	
5 B-W	1	117	
6 B-W	3	14	
6 C	2	38	
8 B-W	5	19	
9 B-W	1	50	
11 B-W	2	21	
13 B-W	1	88	
16 B-W	1	18	
20 C	1	93	
21 B-W	1	2	

* B-W = black-and-white; C = color

the midpoint, with 21 damages or a total of 885 ft. Two damages involving 10 ft were recorded from the midpoint on, with 2 damages at the end for a total of 39 ft.

In damages of 1,600-ft films, as outlined in Table V, a total of 22 partial damages was recorded. At the beginning of the film, 4 damages were found for a total of 94 ft. In the portion of the film up to the midpoint, 11 damages were recorded for a total of 2,150 ft. This seems to be an extraordinary amount of damaged footage for only 11 damage cases. From 800 ft on, but 3 damages were found with a total of 39 ft involved. Four damages were located at the end of 1,600-ft films, amounting to 189 ft.

Comparing monthly circulation of films with the number of damages per month, Table VI draws these data out in some detail for 400-ft films. In October, the Audio-Visual Center circulation was 10% of the year's total, with 12% of the year's partial damages and 30% of the total or complete damages falling during this month. In September, with but 7% of the annual circulation during that month, 15% of the year's complete damages were found. February, with the second highest monthly circulation for the year, had 18% of the partial damages as well as the greatest number

Table III. Analysis of Partial Damages in 800-Ft Films

Damage Code No.	Total No. of prints	Average footage per damage	Point at which damage starts
Beginning of Film			
1 B-W*	15	25	
1 C	4	72	
4 B-W	1	326	
5 B-W	1	3	
8 B-W	4	32	
10 B-W	1	8	
10 C	2	9	
16 B-W	1	22	
27 B-W	1	15	
First 400 Ft			
1 B-W	7	33	174
1 C	2	153	125
4 B-W	2	10	40
5 B-W	2	4	100
6 B-W	5	16	197
8 B-W	5	3	134
10 B-W	2	27	115
17 B-W	1	3	31
Last 400 Ft			
1 B-W	2	6	630
1 C	2	32	406
6 B-W	1	3	455
8 C	2	5	428
10 B-W	1	23	571
20 B-W	1	33	488
End of Film			
1 B-W	1		
6 B-W	1		

* B-W = black-and-white; C = color

Table IV. Analysis of Partial Damages in 1,200-Ft Films

Damage Code No.	Total No. of prints	Average footage per damage	Point at which damage starts
Beginning of Film			
1 B-W	3	35	
3 C	1	25	
4 B-W	1	18	
5 B-W	1	30	
First 600 Ft			
1 B-W	9	24	279
1 C	1	3	273
4 B-W	3	5	200
6 B-W	3	72	222
7 B-W	1	67	318
8 B-W	2	159	466
9 B-W	1	3	484
10 B-W	1	47	135
Last 600 Ft			
1 B-W	1	4	1,125
4 B-W	1	6	837
End of Film			
6 B-W	1	30	
21 B-W	1	9	

* B-W = black-and-white; C = color

Table V. Analysis of Partial Damages in 1,600-Ft Films

Damage Code No	Total No. of prints	Average footage per damage	Point at which damage starts	Damage Code No.	Total No. of prints	Average footage per damage	Point at which damage starts
Beginning of Film				9 B-W	2	415	280
1 B-W*	2	31		Last 800 Ft			
6 B-W	1	20		1 B-W	2	10	1,426
16 B-W	1	12		8 B-W	1	19	1,083
First 800 Ft				End of Film			
1 B-W	6	125	322	1 B-W	2	65	
6 B-W	2	280	49	6 B-W	2	29	
8 B-W	1	10	576				

* B-W = black-and-white; C = color

Table VI. Percentage Analysis of Partial and Complete Damages of 400-Ft Films Distributed Each Month of a Fiscal Year

Mo.	Films circulated	% of films circulated	No. of damaged sections	% of damaged sections	No. of films with partial damages	% of partial damages	No. of total damages	% of total damages
July	1,343	2.72	5	1.86	5	2.04	0	0
Aug.	813	1.65	5	1.86	5	2.04	1	2.50
Sept.	3,825	7.76	23	8.57	20	8.16	6	15.00
Oct.	5,347	10.85	33	12.31	30	12.24	12	30.00
Nov.	5,528	11.23	23	8.57	23	9.30	5	12.50
Dec.	4,158	8.45	27	10.07	25	10.20	2	5.00
Jan.	4,844	9.14	15	5.22	15	6.12	3	7.50
Feb.	5,853	11.88	53	19.77	45	18.36	1	2.50
Mar.	7,111	14.44	41	15.29	38	15.05	4	10.00
Apr.	5,692	11.34	22	8.20	18	7.37	3	7.50
May	3,504	7.12	21	7.83	20	8.16	3	7.50
June	1,253	2.54	0	0	0	0	0	0
Total	49,271		268		244		40	

Table VII. Percentage Analysis of Partial and Complete Damages of 800-Ft Films Distributed Each Month of a Fiscal Year

Mo.	Films circulated	% of films circulated	No. of damaged sections	% of damaged sections	No. of films with partial damages	% of partial damages	No. of total damages	% of total damages
July	1,343	2.72	0	0	0	0	0	0
Aug.	813	1.65	0	0	0	0	1	11.11
Sept.	3,825	7.76	7	10.01	6	10.00	0	0
Oct.	5,347	10.85	7	10.01	4	6.66	1	11.11
Nov.	5,528	11.23	9	13.07	8	13.33	1	11.11
Dec.	4,158	8.45	3	4.34	3	5.00	2	22.22
Jan.	4,844	9.14	4	5.80	4	6.66	2	22.22
Feb.	5,853	11.88	8	11.59	7	11.66	0	0
Mar.	7,111	14.44	15	21.73	12	20.00	2	22.22
Apr.	5,692	11.34	8	11.59	8	13.33	0	0
May	3,504	7.12	7	10.01	7	11.66	0	0
June	1,253	2.54	1	1.45	1	1.66	0	0
Total	49,271		69		60		9	

of films with more than one damaged section per film. Remarkably, only 2.5% of the year's complete damages occurred in February. With 14% of the year's circulation falling in March, 15% of the partial damages occurred along with 10% of the complete damages.

As outlined in Table VII, November proved to be the autumn month for the greatest percentage of partial damages in 800-ft films, namely, 13%. For the spring period, March, with 14% of the film circulation, had a very high 20% of the complete damages.

February, with 11% of the film circulation, had 21% of the partial damages and 40% of the year's complete damages for 1,200-ft films. Table VIII shows the greatest amount of partial damages occurring in March, a destructive 25%.

Table IX indicates that during the month of March, 30% of the damages to 1,600-ft films occurred.

Complete or total damages of all

Table VIII. Percentage Analysis of Partial and Complete Damages of 1,200-Ft Films Distributed Each Month of a Fiscal Year

Mo.	Films circulated	% of films circulated	No. of damaged sections	% of damaged sections	No. of films with partial damages	% of partial damages	No. of total damages	% of total damages
July	1,343	2.72	0	0	0	0	0	0
Aug.	813	1.65	4	12.50	1	3.57	0	0
Sept.	3,825	7.76	2	6.25	2	7.14	0	0
Oct.	5,347	10.85	2	6.25	2	7.14	1	20.00
Nov.	5,528	11.23	4	12.50	4	14.28	1	20.00
Dec.	4,158	8.45	3	9.37	2	7.14	1	20.00
Jan.	4,844	9.14	1	3.12	1	3.57	0	0
Feb.	5,853	11.88	6	18.75	6	21.42	2	40.00
Mar.	7,111	14.44	7	21.87	7	25.00	0	0
Apr.	5,692	11.32	3	9.37	3	10.61	0	0
May	3,504	7.12	0	0	0	0	0	0
June	1,253	2.54	0	0	0	0	0	0
Total	49,271		32		28		5	

Table IX. Percentage Analysis of Partial and Complete Damages of 1,600-Ft Films Distributed Each Month of a Fiscal Year

Mo.	Films circulated	% of films circulated	No. of damaged sections	% of damaged sections	No. of films with partial damages	% of partial damages	% of total damages
July	1,343	2.72	0	0	0	0	No total damages of 1,600-ft. films
Aug.	813	1.65	0	8.69	0	0	
Sept.	3,825	7.76	2	8.69	2	9.52	
Oct.	5,347	10.85	3	13.04	3	14.28	
Nov.	5,528	11.23	2	8.69	2	4.76	
Dec.	4,158	8.45	0	0	0	0	
Jan.	4,844	9.14	1	4.34	2	4.76	
Feb.	5,853	11.88	4	17.38	4	19.04	
Mar.	7,111	14.44	7	30.43	7	33.32	
Apr.	5,692	11.34	2	8.69	2	9.52	
May	3,504	7.12	2	8.69	1	4.76	
June	1,253	2.54	0	0	0	0	
Total	49,271		23		21		

films are listed in Table X. With a fair number of color 800-ft films in the library, it is unusual that no complete damages occurred. Yet, with the relatively few 1,200-ft color films in the library, two of these received complete destruction.

Table X. Analysis of Total Damages of Films Circulated During the Fiscal Year

Damage Code No.	Total No. of prints	Damage Code No.	Total No. of prints
..............400-Ft Films..............			
1 B-W*	11	9 B-W	1
1 C	1	10 B-W	4
2 B-W	1	10 C	2
4 B-W	8	11 B-W	1
5 B-W	1	13 B-W	1
5 C	4	14 B-W	1
6 B-W	1	24 B-W	1
8 B-W	2		
....800-Ft Films..		..1,200-Ft Films...	
1 B-W	3	1 B-W	1
5 B-W	1	4 C	1
6 B-W	1	14 B-W	1
7 B-W	1	17 B-W	1
8 B-W	1	28 C	1
9 B-W	1		
10 B-W	1		

* B-W = black-and-white; C = color

Conclusions and Comments

The damage of teeth marks on sound track is no longer as serious as in former years. This may be due to the decreased use of silent projectors or the amount of training given to projectionists. Attempts have been made to include leaflets with film shipments warning the user of the consequences of threading sound film into silent projectors.

Were it not for our constant practice of keeping each film provided with a 5-ft leader and credit title of appropriate length, the reported damages would be much more numerous. On many occasions, various films were saved from damage by the fact that the leader and credit title served as the necessary margin of warning to the operator to stop the machine when the film did not feed correctly.

Evidence seems to support our contention that the training of projectionists is not done systematically. It appears that every year October and February are the periods of greatest relative film damage. During these months new operators are assigned to serve as projectionists. Many damages suggest that the operator did not understand the proper threading of film. Failure of proper loop formation, for instance, accounted for many of the numerous damages at the beginning of films. It is deemed advisable to assign to each projector one 100-ft roll of practice film, so that each projectionist has an opportunity to practice prior to the use of the films. It has been our policy to make available to all users of our films such a practice reel whenever requested and at no cost.

On the basis of total number of films circulated, it is impossible to predict with any great degree of accuracy how many damages to expect during a given month. Table VI, which contains the percentage analysis of damages for 400-ft films, points this out clearly. If the damages in other years were analyzed in the same manner, trends in damage patterns might be shown.

Although 800-ft films comprised approximately 26% of the prints in our film library, only 17% of the partial damages and 17% of the complete damages were in 800-ft films, which helps to support our belief that these require proportionately less maintenance time.

The damaged footage of color film seems higher than one would expect. Probably color films were more heavily booked on the average, hence the chance for damage was greater. This matter would be greatly clarified if exact figures were available relative to the number of color films distributed each month as compared with black-and-white films.

A New Theater Sound System

By B. Passman and J. Ward

A fully integrated sound system designed to meet the needs of regular and drive-in theaters, having power requirements ranging from 20 to 280 watts, features standardized chassis and cabinet design, interchangeable power amplifiers and a plug-in preamplifier located in the soundhead. Use of modern circuit techniques and conservative rating of all components afford reliability and rated performance under all conditions.

THE PERFORMANCE of the system to be described meets or exceeds the specifications recommended by the Motion Picture Research Council.[1] Many operational and service features are provided as a result of considerable experience in the field of theater equipment design.

For all indoor theater systems a standard four-section cabinet contains one or two power amplifiers, a monitor amplifier, a speaker network and an exciter lamp power supply. Preamplifiers are located in each soundhead and in a nonsynchronous control cabinet. A 500-ohm line couples the power amplifiers to the preamplifiers through control cabinets which house the sound change-over switches and volume controls. A control cabinet is mounted on the front wall adjacent to each soundhead.

For the larger drive-in theater systems the standard four-section cabinet contains three or four power amplifiers, each of which feeds one group of In-A-Car Speakers. Single-section cabinets are used for the smaller drive-in systems requiring only one or two power amplifiers. Preamplifier, control and soundhead equipment is similar to that which is provided for indoor theaters with the exception that the exciter lamps are a-c-energized from individual transformers supplied with each soundhead. All systems employing more than one power amplifier are provided with control switches which permit isolation of an inoperative amplifier for service or removal, while maintaining emergency operation with the remaining amplifier or amplifiers.

The standard cabinets are equipped with sliding chassis mounts so that chassis may be withdrawn and inverted while in operation (Fig. 1). Each chassis is provided with a single harness, which is connected by means of self-locking lugs and clamp screws to an accessible terminal board mounted at the front of the cabinet. The chassis are interchangeable and may be disconnected

Presented on October 20, 1950, at the Society's Convention at Lake Placid, N.Y., by B. Passman, International Projector Corporation, Bloomfield, N.J., and J. Ward, General Precision Laboratory, Pleasantville, N.Y.

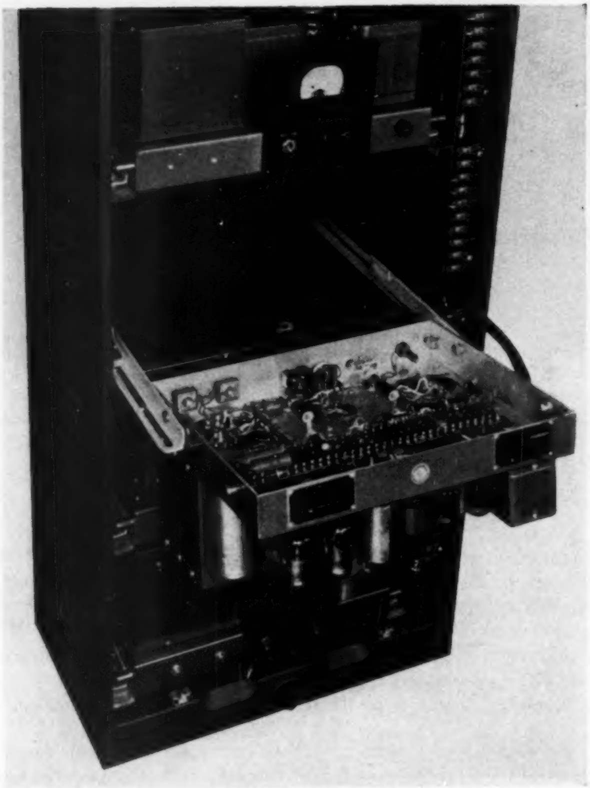

Fig. 1. Chassis inverted for service.

and removed from a cabinet in a few minutes with the aid of a screw driver only.

Soundhead and Preamplifier

Figure 2 shows the soundhead from the operating side. The scanning system layout provides for easy threading and cleaning and the complete assembly is attached to the main frame by means of vibration insulating mounts. Flutter content is held to less than 0.15% as recommended by the Motion Picture Research Council[1] by means of the familiar rotary stabilizer. Dual exciter lamps are mounted on a turret so that a stand-by lamp may instantly be set in position by operation of a convenient lever. An optical system of the stereopticon type, used in conjunction with a vertical filament exciter lamp (9-volt, 4-amp), combines ease of adjustment with exceptional uniformity of sound track illumination.[2] A gas-filled red-sensitive photoelectric cell, type 930, is normally supplied but the blue-sensitive vacuum cell, type 929, may be used without changes if desired.

The gearbox is unit constructed and oil filled to insure precision, quiet operation and long life. Ball bearings are used throughout, and the complete

gearbox is easily removable as a unit. A ¼-hp heavy-duty induction motor provides adequate reserve power and the desired slow starting characteristic is insured by means of a heavy flywheel. A conveniently located brake lever enables the motor to be stopped quickly in the event of film breakage.

A two-stage preamplifier ruggedly built on a plug-in chassis is located in a separate closed compartment at the rear of the soundhead. In this location the amplifier is adequately shielded and protected from dirt and oil. Standard components and regular type 6J7 tubes are used and all connections are made by means of a rugged plug having large-diameter locating pins and silver-plated contacts. Figure 3 is a circuit schematic. In order to stabilize performance and reduce harmonic distortion and microphonic noise, approximately 20 db of inverse feedback is applied from the cathode of the second stage to the input grid. Normal output from a fully modulated sound track into 500 ohms is 6 milliwatts with total harmonic distortion of less than 0.25%. At 60 milliwatts output, the total harmonic distortion is less than 1%. The relative frequency response of the amplifier is within ± 1 db from 50 to 10,000 cycles, and the maximum noise level is 70 db below 6 milliwatts. No noticeable microphonic noise is apparent even when the amplifier is deliberately rattled inside its housing. R14 is a preset gain control with a range of 10 db which is provided for balancing the output from individual soundheads. Low-frequency warping is accomplished by selection of values for R1 and C1.

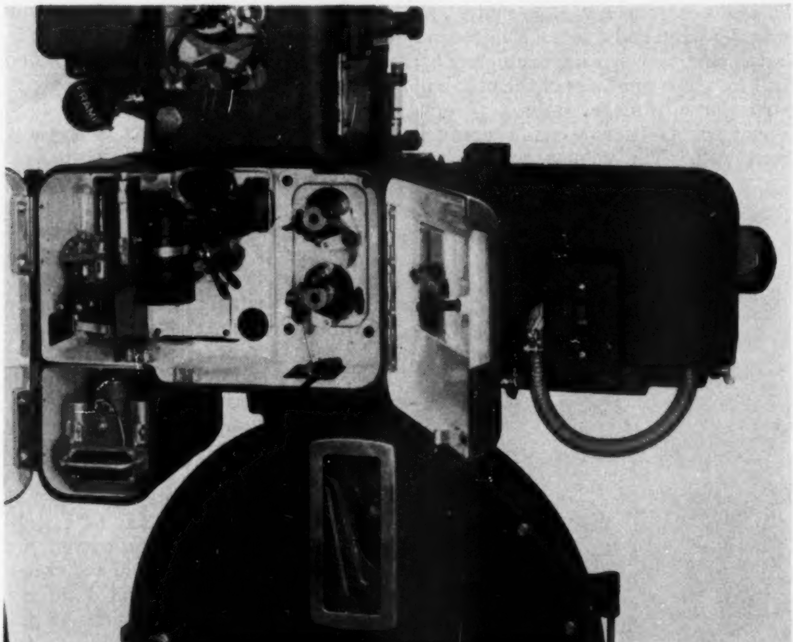

Fig. 2. Soundhead, operating side.

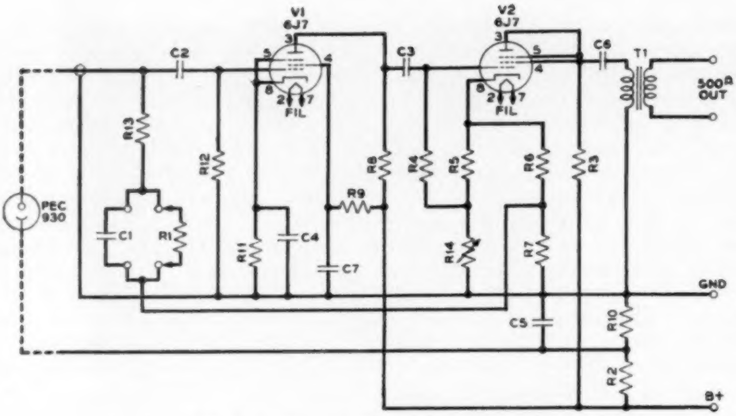

Fig. 3. Preamplifier schematic.

Sound Change-over

Figure 4 shows the control cabinet which is used with each soundhead. This unit contains a volume control, an indicator lamp and a sound change-over switch, and measures approximately 6 x 6 x 7 in. The small size of the unit is of particular advantage, since it permits convenient positioning on a crowded front wall. The volume control is a conventional bridged-T type attenuator having silver contacts and twenty detented 2-db steps, and is connected in the 500-ohm line between the preamplifier and the power amplifiers. The indicator lamp is connected to the sound change-over switch to show which soundhead is in operation.

Fig. 4. Sound change-over cabinet.

The change-over switch is specially designed to eliminate all mechanical linkages between projectors without introducing complicated wiring. The switch is manually closed and latched by means of a push button, but is opened by the action of a solenoid. Figure 5 is a simplified circuit schematic showing two sound change-over stations. The solenoids are energized from the 6.3-volt a-c supply to the preamplifiers and all contacts are directly operated by the push button. Contacts numbered 4 and 5 and 7 and 8 are mechanically latched in the closed position upon operation of the push button as shown at station 1. Contacts 1, 2 and 3 are operated by the push button, but are not latched. Upon operation of the switch at station 2, contacts 2 and 3 are momentarily closed, thus energizing the solenoid at station 1 and releasing the switch. At station 1, contacts 7 and 8 will open and 6 and 7 will close, thus

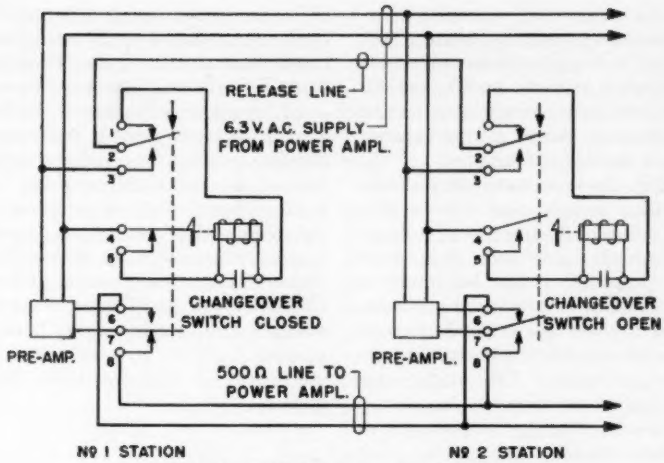

Fig. 5. Sound change-over schematic.

disconnecting station 1 preamplifier from the 500-ohm line and shorting its output. At station 2, contacts 6 and 7 will open and 7 and 8 will close, thus connecting preamplifier 2 to the 500-ohm line. This assures freedom from "break through" from the unused soundhead. Contacts 4 and 5 are provided so that only the solenoid of a latched switch may be energized; this means that however many sound change-over stations are involved, the total current required for changeover is limited to that necessary for one solenoid.

The system is completely silent in operation and entirely reliable. Even in the event of failure of the solenoid system the signal from the "incoming" projector will be connected to the power amplifiers, since the switch contacts are manually closed. Under these conditions the signal from the "outgoing" projector may be disconnected from the power amplifiers by manual release of the latch or by operation of the associated volume control. It will be noted that three lines only are required between stations; of these the 6.3-volt pair and the 500-ohm pair are required for the preamplifiers. The single release line, therefore, is the only additional wire necessary for sound changeover. Furthermore, a third projector or any number of stations may be added by extending the three lines shown without additional complicated wiring. Normal system interconnections also include B plus and ground wiring for the preamplifiers; these connections are not shown since they are not associated with the operation of the change-over switches.

Nonsynchronous Input

In order to provide for convenient connection and control of the nonsynchronous inputs, a separate plug-in preamplifier is provided and is connected to the 500-ohm line through a volume control and change-over switch in the same manner as the soundhead preamplifiers. The additional preamplifier and controls are mounted in the cabinet shown in Fig. 6. The use of a separate plug-in preamplifier and cabinet serves three purposes:

1. A spare preamplifier, warmed up and ready for use, is instantly available as an emergency replacement for the soundhead preamplifiers.

2. A convenient and accessible location is provided for testing preamplifiers with all power supplies connected.

3. Provision is made for the permanent connection, necessary equalization and convenient control of the phonograph and microphone inputs.

Sound change-over between the nonsynchronous inputs and the soundheads is accomplished in the same manner as between soundheads, thus eliminating "juggling" at the beginning or end of the show or at the intermission, and ensuring the same silent nonsynchronous change-over as is obtained between soundheads. The installation and control of the nonsynchronous inputs is regarded as an integral part of the system and not as something to be added at the last moment by the installation engineer.

Also located in this cabinet is the high-frequency warping network. Warping is accomplished by means of conventional filter circuits in the 500-ohm line between the preamplifiers and the power amplifiers, and adjustment of the frequency response over a wide range is effected by strapping and the substitution of capacitors and resistors on the terminal board which is mounted beside the preamplifier. Standard adjustment is in accordance with the Motion Picture Research Council's "Standard Electrical Characteristic for Theatre Sound Systems,"[1] and in addition to the usual variable "roll-off" provision is made for increasing the response in the 3000- to 4000-cycle region.

Power Amplifiers

To provide for regular and drive-in theater sound systems requiring from 20

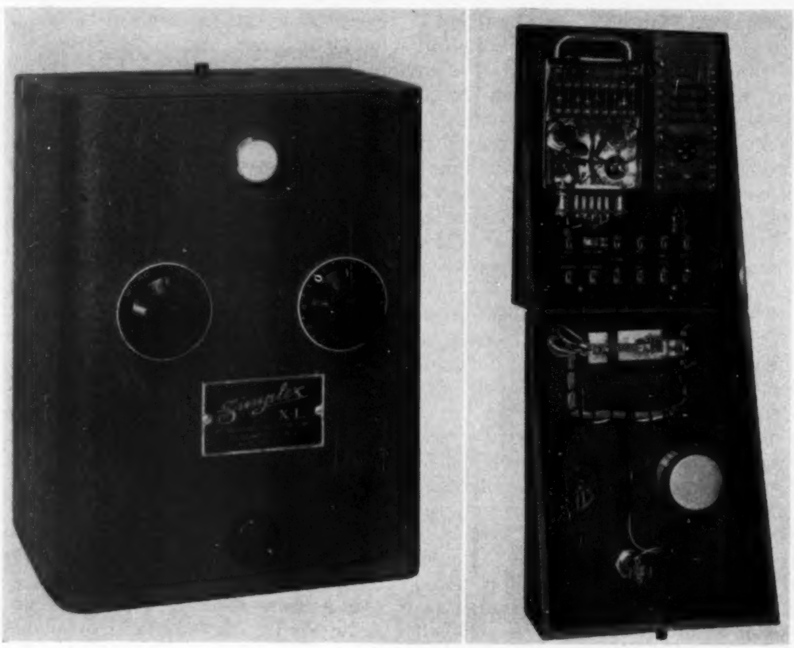

Fig. 6. Nonsynchronous input control cabinet.

to 280 watts, two power amplifiers have been designed. The amplifiers are constructed on the same standard chassis and are, therefore, interchangeable. Figure 7 is a schematic diagram of the larger amplifier. For regular theater use this amplifier is conservatively rated at 60 watts with less than 2% total harmonic distortion from 50 to 5,000 cycles. For drive-in theater use the amplifier is rated at 70 watts since maximum power output at very low frequencies is not required for the operation of In-A-Car speakers. Type 807 tubes are operated in push-pull AB2 with fixed bias and a regulated screen supply. Voltage regulator tubes V6 and V7 are used to control the screen voltage and a selenium rectifier CR1 and CR2 provides the bias voltage. The 807's are driven by a low-impedance source consisting of push-pull cathode followers V3. In this manner the output tubes are operated strictly within design center ratings and maximum power is assured under all conditions.

The phase inverter is of the "floating-paraphase" type, employing double triodes V1 and V2 connected in "cascode" (plate-to-cathode coupled). This arrangement provides the necessary gain and voltage swing with but one coupling circuit, thus permitting the use of negative feedback around the entire amplifier. The use of considerable negative voltage feedback from the secondary of the output transformer T2 to the cathode of the first tube VI would normally result in an exceptionally low internal output impedance. For optimum performance of the speaker system, however, the internal impedance of the amplifier is increased to approximately 0.7 times the speaker load impedance by the application of some negative current feedback which is obtained from the current flowing through the secondary of the output transformer and the resistor R34. The total inverse feedback of approximately 12 db reduces harmonic distortion and stabilizes performance; relative frequency response is within ± 1 db from 50 to 10,000 cycles and the noise level is 35 db below 6 milliwatts.

The amplifier input transformer T1 is designed to bridge across a terminated 500-ohm line and full output is obtained when the level in the 500-ohm line is −20 db with reference to 6 milliwatts (0.173 volts). Since all gain-control and warping adjustments are effected in the preamplifiers and the 500-ohm line, power amplifier gain and frequency response is standardized and amplifiers may therefore be operated in parallel without balancing or adjustment of any kind. Full rated power for regular theater systems employing dual amplifiers is therefore assured. For drive-in systems employing multiple amplifiers the inputs are connected in parallel but each amplifier output feeds one group of speakers.

The smaller power amplifier differs from the 70-watt amplifier only in the following respects:

1. Type 6L6 tubes operating in push-pull AB1 are used in the output stage.
2. Voltage regulator tubes are not necessary and only one rectifier tube is required.
3. A single twin triode serves for the "floating paraphase" phase inverter.

All features of the larger amplifier are retained and the performance is identical, except for the power output which is 20 watts with less than 2% total harmonic distortion from 50 to 5,000 cycles.

Exciter Lamp Power Supply

The exciter lamp power supply is constructed on a standard chassis and is mounted in the four-section cabinet in the same manner as the power amplifiers. The power supply provides 9 volts 8 amp of direct current so that only a single unit is required for a normal two-projector system.

A voltage-regulating transformer is used to ensure constant exciter lamp current and hence to minimize the effects of varying line voltage on system

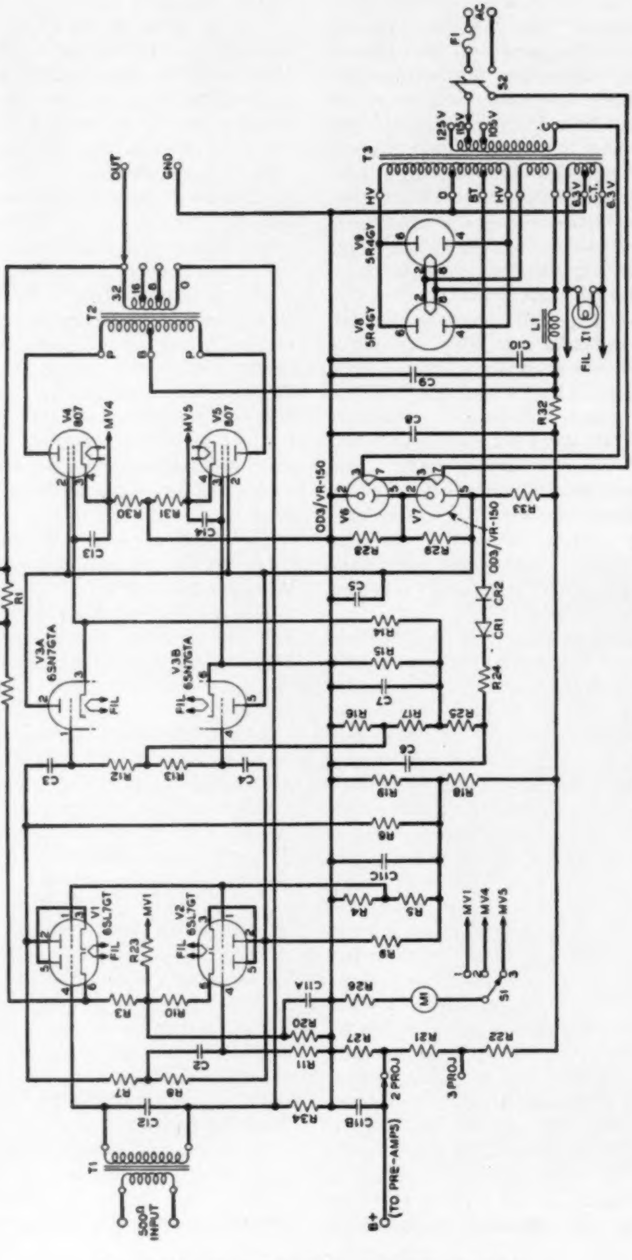

Fig. 7. Power amplifier schematic.

gain. For reliable operation with freedom from maintenance, a bridge-type selenium rectifier is used; extended life tests indicate that conservatively rated high-quality selenium rectifiers may be expected to operate satisfactorily for the normal life of the equipment. A two-stage L-C filter results in a ripple content of less than 5 millivolts which, with 9-volt 4-amp exciter lamps, does not contribute to the system noise level.

Individual preset controls are provided for setting and balancing the supply to each exciter lamp. Current-type relays in series with each lamp are arranged to connect a dummy load resistor to the power supply in the event that either exciter lamp burns out. A standby switch provides for emergency operation of the exciter lamps from alternating current in case of failure of the rectifier or filter circuits.

For drive-in systems operating with In-A-Car speakers a d-c exciter lamp supply is not necessary. Exciter lamps having heavier filaments (10-volt 7.5-amp) are supplied with alternating current from transformers associated with each soundhead.

Stage Speaker Equipment

To ensure optimum over-all performance, new speaker equipment has been designed and engineered by Altec Lansing as an integral part of the sound system. Figure 8 shows the arrangement of a large speaker system having six low-frequency and four high-frequency driver units. Careful attention to the physical layout of the low-frequency horns has resulted in a remarkable improvement in the uniformity of phasing of the high- and low-frequency units over a wide angle and throughout the entire seating area. Furthermore, the design is entirely flexible since identical low-frequency units may be stacked to accommodate the larger systems.

The high-frequency driver units incorporate a newly developed "acoustic filter cap" which is located immediately behind the diaphragm. In electrical analogy this acoustic filter serves as a condenser in series with the high-frequency voice coil, and hence complements the function of the electrical dividing network below 500 cycles. This acoustic filter contributes appreciably to the smoothness of the high-frequency reproduction, and in particular, improves the over-all response characteristic in the crossover region. This development also provides a safety factor which allows the high-frequency units to handle greater power without danger of damage to the diaphragms.

A single standard electrical dividing

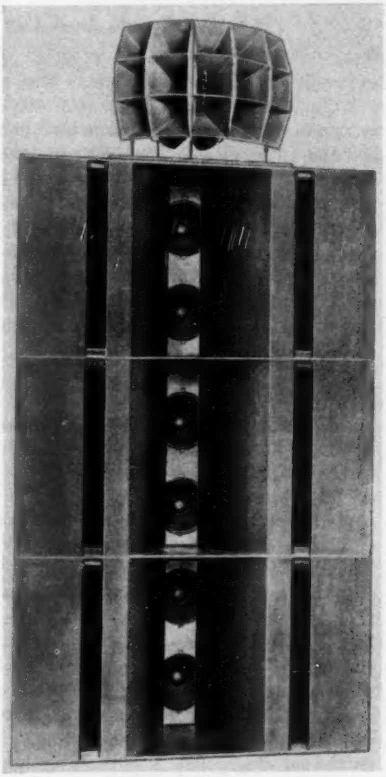

Fig. 8. Stage speaker equipment.

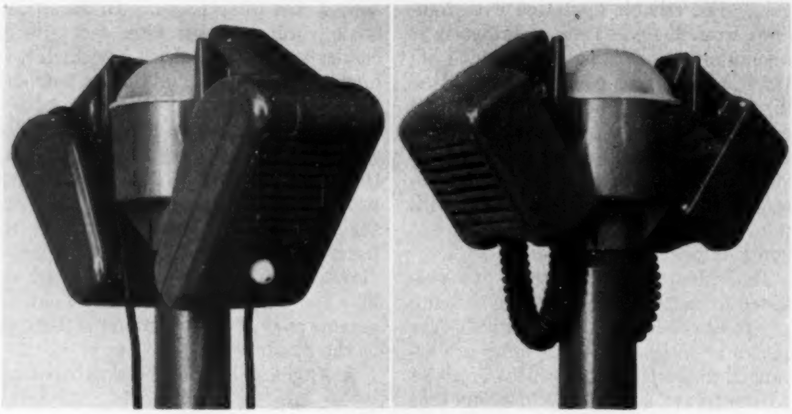

Fig. 9. In-A-Car speaker equipment.

network is used for all systems and is located in the booth. This network is mounted on a chassis which is installed in the four-section cabinet in the same manner as the power amplifiers. Switches are provided for individual control of the high- and low-frequency speakers so that either unit may be isolated in case of emergency. Test facilities in the form of dummy load resistors and a jack are also provided on this chassis.

Monitor Equipment

Also mounted on the network chassis is the monitor amplifier and its associated controls. This amplifier is a self-contained unit which may be disconnected and removed from the network chassis by means of a screw driver only. The amplifier has its own power supply, employs a 6L6 output tube with negative feedback, and is rated at 4 watts. The unit is therefore entirely independent of the power amplifiers and provides adequate power for the monitor speaker under all conditions and without loss of power on the stage line. A combined emergency and monitor amplifier power switch is arranged so that the monitor speaker is operated directly from the stage line when the monitor amplifier switch is in the "off" position.

The monitor speaker is mounted in a reflex-type cabinet and the over-all performance is such that the equipment is of real value for trouble shooting and monitoring sound quality.

Ramp Control and In-A-Car Speakers

A ramp control cabinet is provided with all drive-in systems; each ramp is connected to the power amplifiers through a switch so that the projectionist may immediately isolate a failure, such as a short in the underground wiring. The effect of such a failure may, therefore, be limited to a small group of speakers, thus preventing a general loss of sound throughout the theater. A preset dummy load resistor is connected to each switch and is adjusted to match the associated ramp impedance at the time of installation so that a reasonably constant load is presented to the power amplifiers under all conditions.

Each ramp control panel is provided with twelve ramp switches and the cabinet accommodates one or two panels, as required. One of the control panels, used on all systems, is provided with a

monitor volume control, a monitor selector switch and a line matching transformer. The switch permits selective monitoring of the larger systems having from two to four power amplifiers, each feeding a group of ramps. The use of a monitor amplifier in this application is unnecessary.

In-A-Car speakers (Fig. 9) are available in two sizes, one having a $3\frac{1}{2}$-in. speaker unit and the other a 4-in. speaker unit. Both types have rugged die-cast housings finished in baked enamel, and adequately weatherproofed; straight or coiled cords are optional. Volume control is by means of a rheostat and a full off position is provided. The units are designed to withstand considerable patron abuse.

The coupling unit is common to both types of speaker and contains a vacuum impregnated line transformer, a 28-volt lamp and the necessary rugged terminals for the heavy ramp cable connections. The main body is die cast, and has the same durable finish as the speakers. All electrical components are mounted on a terminal panel which is retained vertically between slots in the coupling unit casting. A translucent plastic dome covers the casting and provides a diffused glow which facilitates return of the speakers to the coupling unit at the end of the show. The dome may also be used to indicate ramp and car location numbers. In addition to providing illumination for the dome, the lamp is positioned so that a circle of light is projected onto the ground in front of the post. This combined post-and-dome lighting has been found to be most effective in protecting the equipment from accidental damage.

Installation procedure is simplified by shipping the coupling unit as parts instead of complete assemblies. The casting is first mounted on the post, then the terminal panel is dropped in place and all ramp and speaker connections made. After tests, the plastic dome is placed on the casting and retained by a special locking device.

Conclusion

Simplex XL sound equipment is already in production and systems have been installed in many indoor and drive-in theaters. Initial reports received from service and installation engineers, projectionists and exhibitors highly commend the flexibility of installation, operational features and high quality of sound reproduction.

References

1. "Standard Electrical Characteristics for Theatre Sound Systems," Technical Bulletin of the Motion Picture Research Council, Inc., April 20, 1948.
2. F. E. Carlson, "Properties of lamps and optical systems for sound reproduction," *Jour. SMPE*, vol. 33, pp. 80–96, July 1939.

The Cooling of Film and Slides in Projectors

By Hugh McG. Ross

A heat-absorbing filter is of primary importance for cooling film or slides, and experimental results are given of the performance of various types. A good filter, combined with a more powerful lamp, allows the screen illumination to be doubled without affecting the film. A study of the heat flow within the film during exposure leads to estimates of the efficacy of methods of film cooling which may be used in the future. The theory of cooling slides shows that best results are given by blowing air at very high velocities across the slide, to remove the "blanket" of stagnant air adhering to the surfaces. A practical slide cooler is described, and its performance figures given.

In virtually every projector the designer and users are faced with the problem of the heating of the film or slide in the gate. This is particularly severe with high-power theater projectors or process projectors used in film studios for front- or rear-projection shots, or when the output of substandard moving or strip-film projectors is increased. In the most powerful of present-day projectors, the heating of the film is the limiting factor, and for projectors to be made with greater light output it will be necessary to use some method of reducing the heating effect. There are two ways of tackling the problem: the first is to reduce the amount of heat at the gate by filtering out unwanted radiation, and the second is the cooling of the film or slide in the gate.

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Filtering of Radiation

The film or slide is heated by the absorption of the radiant energy in the light beam. This absorption takes place in the silver or dye image, only a negligible amount being absorbed by the base material.[2] The wavelength of the energy which is absorbed is of no consequence—visible and invisible radiation both contributing to the heat—and it is therefore possible to obtain a marked reduction in the heating by filtering out the radiant energy of wavelengths which do not contribute to the final visual or photographic effect. Removal of the infrared radiation is the most important, although it is sometimes of value to remove also the ultraviolet radiation emitted by the high-intensity arc.[3] This has to be done, however, without altering the color of

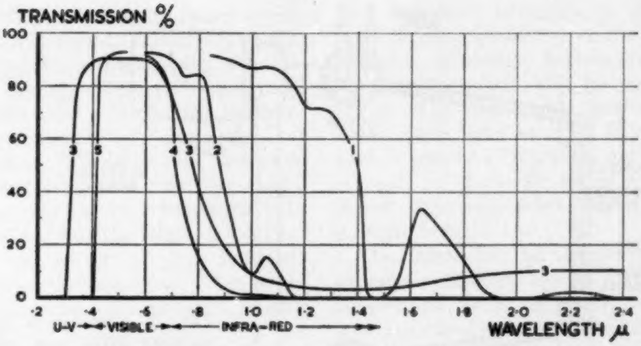

Fig. 1. Transmission curves for various filters for absorbing unwanted infrared or ultraviolet radiation.

Curve 1, water 0.2 cm thick, in glass cell; *Curve 2*, water 5 cm thick, in glass cell; *Curve 3*, Chance's ON20 glass, 0.2 cm thick; *Curve 4*, aqueous solution of ferrous ammonium sulfate, 52 gm per liter, 5 cm thick, in glass cell; *Curve 5*, aqueous solution of orthonitrobenzoic carbonate.

the transmitted light and also with the minimum reduction of the useful light.

Heat-Absorbing Filters. Figure 1 shows the absorption curves of some typical infrared filters. It will be seen that water,[4] even in a very thin layer, is virtually opaque to radiation above 2.35 microns (1 micron = 1 μ = one-thousandth of a millimeter). This is of particular value in keeping cool the lenses and other parts of the optical systems, for crown glass begins to absorb quite heavily at longer wavelengths than this.

The most efficient infrared filter is provided by ferrous sulfate or ferrous ammonium sulfate dissolved in water. The addition of a few drops of sulfuric acid makes the solution more stable. A convenient way of preventing the formation of air-bubbles on the windows of the cell is to add a few drops of detergent or wetting-agent, which prevents the released air from adhering to the windows. A solution of the strength shown, when in a cell 5 cm thick, has a very pale blue-green color, due to slight absorption of the deep-red part of the visible spectrum, but for most applications this is hardly visible.

Perhaps the most convenient infrared filter is provided by type ON20 heat-absorbing glass made by Chance Bros.[5] This is almost colorless (the curves of Fig. 1 have been drawn for ferrous ammonium sulfate and ON20 glass filters appearing visually to have the same color) while it absorbs well in the near infrared. Its transmission increases slightly as the wavelength increases and only becomes negligible above 3.4 μ. For many applications this type of filter is suitable, and the heat which it absorbs may be dissipated by natural convection to the air, or the glass may be cooled by blowing air on it.

Combined Heat-Absorbing Cell and Lens. It is probable, however, that the most suitable infrared filter for practical use in a high-power projector is a combination of a thin layer of water with a sheet of ON20 glass. This absorbs well in the near infrared, provides full protection to the lenses and is reliable and stable in use. Figure 2 shows diagrammatically such a filter combined with the first condenser lens of a process projector.[6] The arc runs at 300 amp with a 16-mm positive carbon,

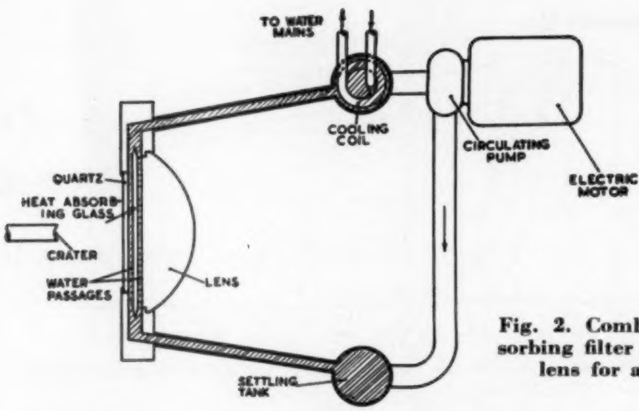

Fig. 2. Combined heat-absorbing filter and condenser lens for a projector.

and 2¾ in. away from this is the front window of the cell 5¼ in. in diameter. This window is made of quartz in order that it may readily withstand the heat of the arc and its flame. On the other side of the quartz there is a narrow water channel, the water being constantly circulated by a pump and motor. The efficiency of cooling the quartz, and the whole front metal plate of the cell facing the arc, is so good that after running the arc at 300 amp for 30 min it is possible to switch off, open the arc door and immediately hold one's hand against the quartz. A further consequence is that the cool quartz window is relatively little damaged by spatter from the arc, and being quite easily replaced, it acts instead of a spatter glass.

The light, after passing through the quartz and first water channel, passes through a sheet of ON20 glass and into a second water channel. The water channels serve the double purpose of cooling the ON20 glass, and also contributing to the filtering of the light. In particular, the first water channel absorbs much of the infrared radiation, thereby reducing the amount which the ON20 glass has to absorb.

If only a heat-absorbing cell were required, the farther window could be made of optical glass. But in this present example the light next passes into the first condenser lens of the optical system. Because the filter has removed the radiation of wavelengths which might be absorbed by the glass, the lens does not get unduly hot and it is therefore made of crown glass for best optical performance. Similarly, the other lenses of the system are not heated seriously.

Only a small quantity of distilled water is circulated continuously around this cell, and the heat which passes into it is removed by a simple heat exchanger comprising a coiled tube through which mains-water is flowing.

The total amount of heat taken up by this cell is 3600 w. About one-third of this is unwanted radiation removed from the light beam, and the remainder is radiated on to the metalwork of the cell which is in the hot lamphouse.

It is estimated that such a cell and lens absorb only 10% of the visible light, compared with an ordinary lens. This is, in effect, recovered by avoiding the use of a separate spatter glass.

Absorption of Ultraviolet Radiation. In Fig. 1 are also shown two absorption curves in the ultraviolet region of the spectrum. Type ON20 glass is not

greatly different from ordinary crown glass in this region. Good absorption may be obtained when using a water-cell by adding orthonitrobenzoic acid and a little sodium carbonate; this solution is colorless.

Luminous Efficiency of Radiation. The relationship between the useful visual quality of light, compared with its unwanted heating effect, is best expressed in terms of the luminous efficiency of the radiation. This represents the amount of visible light (usually measured in lumens) divided by the total heat in the radiation (which may conveniently be measured in watts). It is therefore given in lumens per watt, and when comparing light sources and filters we want this figure to be as high as possible.

For these experiments the visible light was measured with an accurately calibrated visual photometer, and the total radiation was measured by the rate of heating of a blackened metal block, an allowance being made, of course, for its normal cooling to the air.

In Table I the figure for unfiltered tungsten light is experimentally determined, and due to the inaccuracies likely to arise is only approximate. This luminous efficiency of radiation must be distinguished from the over-all luminous efficiency, lumens per electrical watt, which will be somewhat lower. The four-times improvement to tungsten light at 3100 K obtained with 2 mm of ON20 glass may be increased to about six-times by using 3-mm thickness, with slightly more greenish color.

The figure for the unfiltered arc is experimentally determined, and may be subject to some error. An attempt was made to observe only the crater and a small part of the flame above it. In practical terms, the luminous efficiency of the radiation from a mirror-arc projector system is only slightly higher than this, the glass of the mirror giving little filtering.

The improvements to be obtained by filtering the arc are experimentally measured and are reasonably accurate, being also supported by a considerable number of indirect experiments. A two and two-tenths-times improvement over the open arc can be obtained. When modifying a projector by adding a heat-absorbing cell the improvement will not be quite so great.[7]

The negligible absorption of visible

Table 1. Luminous Efficiency of Radiation.

Light source and filter	Luminous efficiency of radiation, lm/w	Absorption of visible light
Tungsten projector bulb, Class A1, 3100 K, 500-w, 110-v	26	—
Tungsten bulb (3100 K) filtered through 2 mm of ON20 heat-absorbing glass	105	12%
Full sunlight	80	—
High-intensity arc, 290-amp, 16-mm positive	85	—
High-intensity arc, filtered through 5 cm water	155	15%
High-intensity arc, filtered through 5 cm water and 2 mm ON20 glass	190	21%
High-intensity arc, through combined heat-absorbing filter and lens	190	0%
White light (5500 K) with no ultraviolet or infrared (0.4–0.7 μ)	220	—

light when using the combined filter and lens is based on the avoidance of the use of a spatter glass.

The last item is the theoretical figure for the maximum luminous efficiency which could be obtained for white light (from a black-body at the optimum temperature, 5500 K), if perfect filtering of the ultraviolet and infrared could be devised.

Employment of Heat-Absorbing Filters. If a projector is causing damage to film by overheating, this may be cured by the addition of a simple heat-absorbing filter. There will, however, be a slight loss of visible light.

It is very much better if the heat-absorbing filter can be incorporated in the projector when it is being designed. In general, the light output of modern projectors is limited by the heating of the film, lamps and carbons being available with a considerable reserve of output. The inclusion of a filter in a projector when it is being designed, combined with a larger lamp, makes possible a doubling of the light output, compared with a projector without a filter. Whenever a projector with very great light output is required, it is inescapable that a filter should be used; it is, furthermore, the easiest way of giving a significant amount of protection to the film, and it should always be used before other methods are incorporated in the projector.

Heating of Film in Moving Projectors

The main heating effect on film in a moving projector is due to the absorption by the emulsion or dye of most of the heat energy in the light beam. The subsequent effects are, however, very different from what happens to anything which is exposed to the light beam for any considerable length of time. Due to the thermal capacity of the piece of film in the gate, the influx of heat cannot raise the temperature instantaneously, and the temperature therefore rises continually throughout the exposing period. Equilibrium is never established; instead, there is a continuous flowing of heat within the film during the exposure. The effect of the thermal capacity of the film and the short time of illumination combine to make it possible to subject film in a moving projector to intensities of light and heat about ten times greater than could ever be attained with stationary film.

Theory of Heating of Film When Exposed to Light. The exact behavior of the heat within the film during exposure has been established by Brian S. Kellett, and the mathematical treatment is given in an appendix to the author's original paper.[1] The light and heat are absorbed by the silver particles in the emulsion layer which, due to its thinness, rises rapidly in temperature. The heat attempts to flow into the base material, but emulsion is a poor conductor of heat, and film base is even worse, and as a consequence the heat does not have time, during the brief exposure period, to travel far into the base.

The temperatures throughout the thickness of the film at the end of the exposure period are sketched in Fig. 3. This refers to a process projector; in a theater projector with a flicker blade on the shutter the heat travels slightly further into the base.[2] The following points arise:

(1) There is only a small drop in temperature through the emulsion layer.

(2) The temperature of the emulsion is much higher than the average temperature of the base. This causes curl or buckling of the film in the gate soon after the beginning of the exposure,[8] and the objective lens has, therefore, to be refocused slightly.

(3) The heat travels only a very short distance into the base during the exposing period and only about 1/1000 in. of the base is heated significantly.

(4) The rise of temperature of the far surface of the base during the exposing

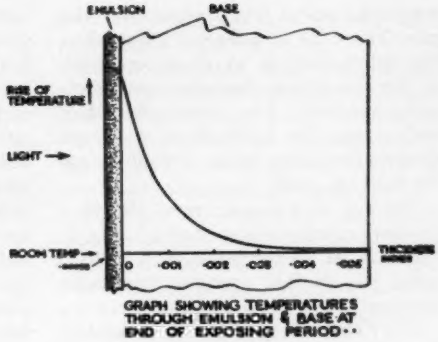

Fig. 3. Enlarged cross-sectional view of film.

The graph shows distribution of temperature within the emulsion and base at end of exposing period in the gate. Only 1/1000 in. of the thickness of the base is heated significantly.

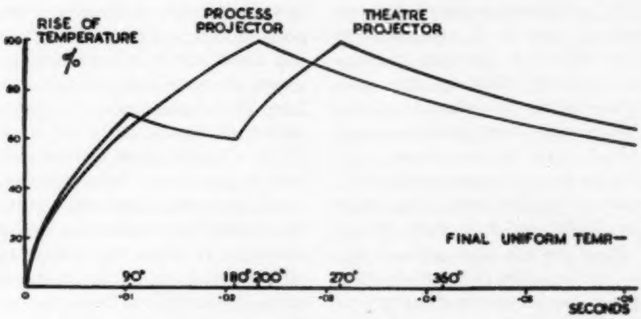

Fig. 4. The heating cycle of film while in the projector gate.

The rise of temperature is calculated for the emulsion side of the base. The maximum value reached depends on the light output.

period is about 1/100 of that of the emulsion side of the base.

(5) At the end of the exposing period about one-eighth of the heat is in the emulsion and the remainder is in the base.

(6) It makes little difference whether the light falls on the emulsion side or the base side of the film.

(7) The average density of the print makes but little difference—only practically full whites are significantly cooler.

Temperatures in the Base. Due to the fact that overheating of film first damages the base, rather than the emulsion, it is necessary to consider more particularly the hottest part of the base—that next to the emulsion. Figure 4 shows the temperature of the emulsion side of the base during the exposing cycle. In a theater projector the temperature rises rapidly at first as the light comes on to the particular frame considered, and then falls somewhat as the flicker blade obscures the light — the heat is spreading deeper into the base. During the second exposing period the temperature again rises; in the figure this part of the curve is to some extent estimated. After exposure is completed the heat now in the film (and mainly concentrated in the first thousandth of an inch of the base) spreads throughout the thickness of the base. This spreading is virtually

completed about four frames after the gate (i.e., 4/24 of a second later) when the whole film is at about one-fifth of the maximum temperature previously reached. The whole film then very gradually cools down to room temperature after being wound up on the take-up spool.

The rise of temperature of film in a process projector is also shown in Fig. 4. There is no flicker blade, and a 200° angle of shutter opening has been assumed.

The False Idea of "Gate Temperature." From this argument it is clear that the concept of "gate temperature" has no real meaning, and it is valueless to attempt to define or measure it. Instead, the heating effect in the gate must be referred to the intensity of the radiant flux—the "instantaneous net flux"[2]—which can be expressed, for example, in watts per square centimeter. The effects on the film have been fully studied by Kolb[2] and it is only on the basis of these results and general experience, in conjunction with the knowledge of the luminous efficiency of the filtered light, that it is possible to consider how to increase the light output of moving film projectors beyond the level at which damage now occurs.

Performance of Contemporary Projectors. The foregoing theoretical approach gives the conclusion that the temperature of the emulsion side of the base will rise 100 C (above room temperature) in a typical theater projector giving a light output of 9500 lm. (Light output measured with shutter running; instantaneous intensity of radiant energy at gate, 62 w/sq cm; unfiltered arc light at 95 lm/w; illumination assumed uniform over the gate.) These figures are in reasonable agreement with experience and measurements made on various projectors,[2,7] and suggest that the maximum instantaneous rise of temperature which film will withstand without damage is of this order.

Present-Day Process Projectors. An example of the best performance obtainable now is given by a 35-mm process projector in which every part of the system is developed to its optimum condition. The arc operates at 300 amp with a 16-mm positive, which gives the greatest light intensity consistent with quiet and steady burning. Any increase would result in more noise and greater unsteadiness, or would require a larger carbon with its lower surface brightness. The optical system, incorporating the combined heat-absorbing cell and first condenser lens described earlier, accepts a large proportion of the light from the arc, and this could not be increased very greatly. A relay condenser system ensures uniform illumination over the gate and the objective lenses have an aperture of *f*/1.4. Any change to the optical system to give more light would probably result in nonuniform illumination over the screen or a reduction of definition, particularly since the defocusing effect of film buckling in the gate might become apparent. The light output on the screen is about 50,000 lm, and this is only a little less than the maximum amount of heat which the film will withstand, based on the curve of Fig. 4. (Light measured with shutter not running; instantaneous intensity of radiant energy at gate 58 w/sq cm; well-filtered light at 190 lm/w.) Since each part of this projector is pulling its full weight, it would be difficult to obtain any marked increase in output, although small increases could be made at the price of reduced silence, or less stability and uniformity of illumination or definition, if this could be tolerated in other applications. It is probable, however, that any increase of picture brightness could more easily be obtained by modification to the screens, by silvering, beading or a simple type of lenticular screen.

Air Cooling of Film. With the aim of overcoming the limitation presented by

the overheating of film, consideration may be given to possible methods of cooling film (after filtering the light, of course). Unfortunately, it is the case that air cooling of film in a moving projector does not permit any great increase of light output. It is shown later that there is a theoretical limit to the maximum amount of heat which can be extracted from a surface, such as the emulsion; this is determined primarily by the speed of sound in air, and by the maximum temperature which the film will withstand. Under best conditions, air cooling can remove about 7 w/sq cm, but the acceptable rate of heating of film in a moving projector is about 50 w/sq cm (mean net flux). Air cooling, therefore, in itself can only permit an increase in light output of about 15%,* although Kolb has shown[2] that high-velocity air jets serve a useful, but different, function in helping to hold the film flat in the gate.

Future Developments. Should the need ultimately arise, it is, however, possible to foresee moving projectors with several times as much light output as those of today, perhaps using a "blown-arc" or large arcs and different optical systems. Looking into the future, we may tentatively consider some of the means of preventing the additional light from damaging the film, several of them being well known. In every case, of course, it will be necessary to filter the light.

(1) Using 70-mm film would permit four times the gate area but probably only about three times as much light, since grave difficulties might be experienced with maintaining the film flat in the gate; there would also be much disturbance to printing and processing equipment.

(2) Running the film faster would give it less time in the gate, but reference to Fig. 4 shows that a three-times increase in speed, and therefore three-times film costs, would only permit a two-times increase of light output.

(3) Since the rise of temperature of the rear surface of the base while being exposed is about 1/100 of that of the emulsion side, it will be quite useless to try to reduce the over-all temperature by cooling the rear surface.

(4) It might be possible to surround the gate with a cell with glass windows, filled with liquid, so that the film is immersed in the liquid while it is in the gate. Water is the best cooling medium, and a two and a half-times increase of light could be obtained. Due to the poor conductivity of liquids the temperature distribution through the water would be similar to that shown in Fig. 3 through the film base, except that the heat would penetrate a little further through the water. Even so, only about 0.002 in. thickness of water is absorbing any significant amount of heat. There would be the real complication in drying the film before spooling it, even if another liquid were used.

(5) Cooling with a rapidly moving stream of liquid would be more effective. If glass plates were placed close to the film, to form narrow channels for the cooling fluid which would be pumped through at high velocity, it might be possible to obtain about a four-times increase in the light output.

(6) On several occasions a liquid has been applied to the picture area of the emulsion so that it is evaporated away while in the gate, some of the heat developed in the emulsion providing the latent heat of evaporation instead of heating the base. Only the liquid on the emulsion side of the film assists in preventing damage to the base. The difficulty is that the heat has to travel through the layer of liquid from the

* The relevant experimental results published by Dr. Kolb for film in a moving projector are in the right-hand curve of his Fig. 8 (ref. 2, page 654). This curve shows a maximum increase of light output due to air cooling of 30%, and does not substantiate his claim for a possible increase of 50%.

emulsion to the outer surface of the liquid, where the evaporation to the air is taking place. Due to the poor thermal conductivity, not a great deal of heat is transferred, and instead of evaporating smoothly the liquid might boil off, which might appear on the screen. A high velocity blast of air might assist in preventing this. It is estimated that a two, or perhaps four-times increase of light might be obtained.

(7) Doubling the thickness of the emulsion would only permit a small increase of light, because such a small proportion of the heat is in the emulsion.

(8) Because the basic difficulty arises from the poor conductivity of the film base, some improvement would result if the thermal conductivity or thermal capacity of the base material could be significantly increased. Such a change to the base material appears most unlikely.

It may be concluded that there are several ways in which the light might be increased about four times above the present maximum (after filtering), but each would introduce severe practical difficulties. Even by a combination of the methods at present foreseen it would hardly be possible to obtain a ten-times increase.

Cooling of Slides in Still Projectors

The cooling of slides in a still projector is different from film in a moving projector in that the slide has to remain exposed for a long period and the thermal conditions reach equilibrium. The heat is absorbed from the beam of light at a constant rate whatever the temperature of the slide, but as the slide warms up the efficacy of the cooling increases. After a few minutes the rate of losing heat will become the same as the rate of absorbing it, and the temperature will rise no further. This temperature must not be so high as to damage the slide.

Cooling by Natural Convection of Air. Most simple projectors rely on natural air cooling of the slide, and this method is frequently used successfully for dissipating the heat absorbed by a glass filter, such as Chance ON20 glass. The air adjacent to the glass is heated and rises, thereby causing a natural cooling draught.

In a slide the heat is mainly developed in the dense parts of the picture, but with natural cooling it travels to some extent all over the slide, the whole of it becoming hot. The maximum temperature which gelatin will withstand for 30 min without turning brown is about 180 C and this appears to be the limiting factor, although on some slides the glass will break before the gelatin chars.

With natural convection of air, the rate of cooling is theoretically equal to:

$$0.0004\ T^{1.25}/h^{0.25}\ \text{w/sq cm}$$ [9]

where T = temperature of slide above temperature of air (C)
h = height of slide (cm)

This presupposes no obstruction to the air from the slide-holder, and also no cover glass; the total area is twice the area of the slide, because heat will be lost from both sides. If a cover glass is used, the cooling will be less effective because of poor heat transfer from the emulsion to the cover glass. For cut film sandwiched between two glasses, the cooling will be reduced still further.

Particularly in the case of glass heat-absorbing filters, which can run at a higher temperature than a slide, a significant amount of heat will also be lost by radiation:

$$\text{Rate of cooling} = 5.7.\epsilon.(T_1^4 - T_2^4).10^{-12}\ \text{w/sq cm}$$

where ϵ = emissivity = 0.9 for glass
T_1 = temperature of glass (K)
T_2 = temperature of surroundings (K)

It is found by experiment that the maximum safe intensity of heating of a 3¼-in. square slide without a cover glass is 0.25 w/sq cm. A glass heat-absorbing filter will withstand about 1w/sq cm with natural air cooling.

Forced Air Cooling of Slides. Where a greater light output is required it is necessary to use forced cooling of the slide, air cooling being far the most convenient. A similar technique might be used to remove the heat from a glass heat-absorbing filter, or even a color filter used in color stage effects.

In such a system the dense parts of the picture become hot and the clear parts remain fairly cool. Heat is not conducted well from one part of the slide to another, and it is calculated, and confirmed experimentally, that if a large dark area is adjacent to a large clear area, the temperature has fallen to a third at a distance of about 0.5 cm from the dark area. As a result of this uneven heating and consequent differential expansion, large stresses may be set up in the glass, and failure occurs by fracture of the glass, usually along the boundaries between dense and clear areas.

The slides would be less likely to break if they were made on plates of quartz or a heat-resisting glass (not a heat-*absorbing* glass). Such plates are liable to have small bubbles or blemishes and are costly, so that they would probably have to be re-used, either by transfer-sensitizing them before printing, or by transferring on to them the finished print made on cut film. For studio process work it is preferred to use standard lantern plates, combined with an adequate slide-cooler on the projector.

Action of the Air Stream. The action of the stream of air is shown diagrammatically in Fig. 5, blowing across a greatly enlarged view of one side of the slide. The air in contact with the slide is considered to be at rest, being "stuck" to the slide. Immediately above this "layer" is another, which "slides" on the first, and so on, layer after layer sliding on the previous one. Some distance from the slide these layers become no longer laminar and begin to become unsteady, and further still they become turbulent, eddying and swirling. This whole effect occurs within about 1/50 in. from the slide, within the "boundary layer."

Air is a very poor conductor of heat, which is therefore only to a small extent conducted through the first slow-moving "layers." Thereafter the heat is transferred with increasing effectiveness as the turbulence increases until the heated air is mixed thoroughly into the main air stream. The distributions of velocity and temperature, on passing out into the air stream, are sketched in Fig. 5.

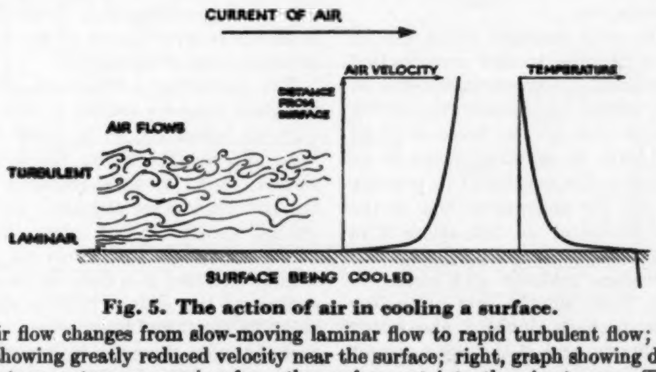

Fig. 5. The action of air in cooling a surface.

Left, air flow changes from slow-moving laminar flow to rapid turbulent flow; center, graph showing greatly reduced velocity near the surface; right, graph showing distribution of temperature on passing from the surface out into the air stream. The thin boundary layer acts as a blanket over the surface.

The chief aim in forced air cooling is to reduce the effect of this slow-moving "blanket" of air over the slide, and this is mainly achieved by using a very high air velocity. Consequently, the temperature of the main stream of air does not rise very much, and a relatively large amount of air has to be used. A great deal of data is available[9] on cooling by air within pipes, which may be of circular or rectangular section. This data may be used if a glass window is placed on each side of the slide to form a tall but thin channel, and the air is blown through this.

The rate of cooling which may be obtained with such a system is equal to:

$$\frac{0.14 . V^{0.75} . \rho^{0.75} . C_p^{0.75} . K^{0.25} T}{t^{0.25}} \text{ watts per sq cm}$$

where V = air velocity, cm/sec
ρ = density = 0.0012 gm/cm^3
C_p = specific heat = 0.24 cal/gm C
K = conductivity = 0.00006 cal/-sec cm^2 C/cm
T = difference in temp. of slide above air, C.
t = thickness of each air passage, cm

It is calculated that in such a system the emulsion side of the slide is only 10 C hotter than the far side, so that the total area cooled is twice the area of the gate.

The important points revealed by this formula are:

(1) The only quantity which can be varied in practice to any great extent is the velocity. Unfortunately due to the 0.75 power, to increase the cooling requires an even greater increase of air velocity, and in addition there is an upper limit to the velocity. In practice this is not the theoretical one of the speed of sound in air, but arises from the fact that at a certain velocity the slide becomes unstable and begins to vibrate. Even so, the rate of cooling could be perhaps doubled above our present limit; and if the light output of the projector is to be increased further the size of the gate must be increased—to perhaps whole-plate size for half a million lumens.

(2) The value of T is determined by the temperature which the slide will withstand without breaking and also by the air temperature. Compared with using air at room temperature, a slight improvement might be obtained by using precooled air. It is, however, difficult to arrange for the supply of a fair quantity of air at a temperature below 0 C, for the cooling equipment becomes covered in ice and frost. Rather than go to this trouble, it is considered to be far preferable to use uncooled air and increase the velocity a little.

(3) It is some advantage to reduce the thickness of the air passages. They must not be made so small as to require too great a pressure to force the air through the slide-cooler, nor to be seriously affected by the usual variations in thickness of the glass of the slide.

Design of a Slide Cooler. A slide-cooler embodying these principles[10] has been developed for a high-power studio process projector,[11] and is shown diagrammatically in Fig. 6. The air is supplied at a small pressure through a nozzle which contracts in the plan view shown, and gets wider in side view until it covers the height of the slide. Another nozzle connects to an exhaust pipe, and providing it is of small angle as shown recovers much of the velocity pressure head at the slide.

The particular advantages of using the glass windows are (1) to obtain the high air velocity; (2) to make it uniform all over the slide; (3) to obtain silence; and (4) they probably make the boundary layer thinner. By using surface-coated optical glass for the windows the light loss is only 6%. One window is fitted in a door to permit insertion of the slide, which is clamped along its upper and lower edges. Along each side edge there is a thin metal strip to give streamlined air flow at the leading and trailing edges of the slide.

Air Supply System. Consideration was first given to obtaining the air from an impellor pump or compressor, but it was found to be impractical to silence such machines sufficiently to permit their use on the projector, which is used unblimped and unboothed on an ordinary sound-recording stage.

The air is therefore obtained from the studio compressed-air supply and the equipment is shown in Fig. 7. It was found that noise occurs wherever there is a marked drop of pressure. All the air passes at full pressure (70 lb/sq in.) through the air filter, which removes water and dust. The pressure is reduced by an ordinary control valve which is surrounded with a small blimp. The loud hissing sound in the air is removed by a most effective silencer, which is itself blimped. The air, now at only 2 to 6 lb/sq in. pressure, passes to the slide-holder and a gauge indicates the air flow. Flexible pipes are provided to enable the slide to be tilted, lifted and panned. The air becomes slightly more noisy on passing

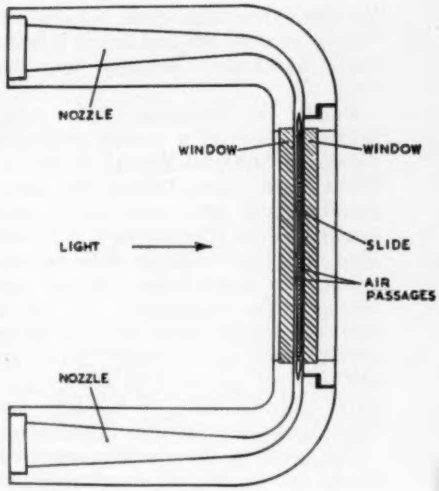

Fig. 6. Diagrammatic cross-sectioned view of slide-cooler.

Glass windows close to each side of the slide form thin channels through which air is blown at a very high velocity.

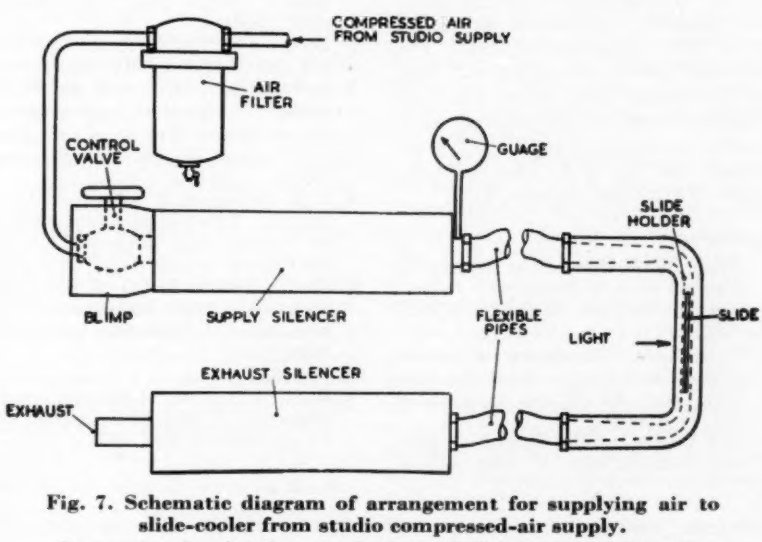

Fig. 7. Schematic diagram of arrangement for supplying air to slide-cooler from studio compressed-air supply.

Pressure is reduced at the control valve, and silencers remove the noise.

the slide at such high speed, but another silencer removes this and the air is practically silent as it exhausts into the room.

Results in Operation. This slide-holder is fitted to a process projector delivering 60,000 lm through a 3-in. × 2.2-in. gate, incorporating the heat-absorbing cell and water-cooled condenser lens described above. It is possible to project ordinary slides of any density for many hours without any damage. The equipment is so silent that it is possible to use it for all shots without troubling the sound recording, and it is not necessary to arrange any sound-reducing flats or blankets between the projector and the microphone.

The quantity of air used is measured to be 50 cu ft/min at atmospheric pressure, giving a calculated air velocity of about 340 mph. The total amount of heat extracted from the slide is 360 w, as measured experimentally.

Acknowledgments. Throughout this work the greatest assistance has been given by Dr. B. V. Bowden, of Sir Robert Watson-Watt and Partners, Ltd., scientific consultants to the J. Arthur Rank Organisation, Ltd. The combined heat-absorbing cell and lens, and the optical system of the high-performance 35-mm process projector mentioned were designed by Mr. A. Warmisham and his staff, and made by Taylor, Taylor and Hobson, Ltd.

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A 35-Mm Process Camera

By John P. Kiel

This paper describes the unique features of the Acme Process Camera and their applications to special effects photography. Basic camera-design features include a color wheel for three-color successive-frame photography, interchangeable film movements with various locations of the register pins, a reflex viewer, embodying register pins in optical alignment with those of the film movement, projection facilities for "matte painting" which allow processed stock to be located on the register pins of the viewer and the image projected through the photographic objective. The electrical and mechanical operation of two new types of drive motors, the Acme stop-motion motor and the variable-speed synchronous motor, and their use in conjunction with the camera are also discussed.

COMMERCIALLY-BUILT process cameras are not commonly used in studios at the present time. Without intending to expand procedures, studio technicians often alter an obsolete production camera to enable it to perform an individual phase of special effects photography. This usually proves quite adequate for one particular procedure; however, the process department is often hampered by the limitations of its equipment.

The Acme Process Camera does not represent a radical change in design or mechanical operation, but presents a combination of technical benefits which have resulted in a more versatile camera which will, in turn, increase the range of activity of the process department.

Presented on April 28, 1950, at the Society's Convention at Chicago, Ill., by John P. Kiel, Producers Service Co., 2704 W. Olive Ave., Burbank, Calif.

The various general attributes of the camera will be considered individually. Their relation to practice is somewhat dependent upon the imagination and ingenuity of the process department; however, the conventional procedures will be annotated.

A feature which will readily be appreciated by the cinematographer is the accessibility of the operating mechanism from the side of the camera (Fig. 1).

Intermittent Film Movement

The highest degree of accurate and positive film registration is essential for color separation negatives, matte shots, and other photographic procedures employed by the process department; therefore, the film movement is of the solid, or stationary, register-pin design (Fig. 2). This particular method of film registration is extremely accurate because there is no mechanical action

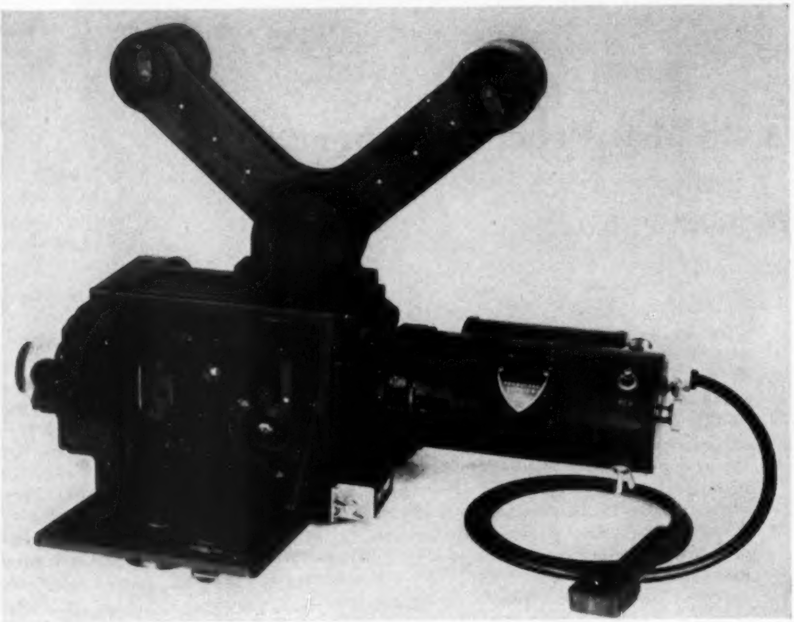


Fig. 1. Internal mechanism, stop-motion motor, and automatic take-up device.

or motion of the register pins. They are mounted directly to the movement base plate.

The register pins are in horizontal alignment. One register pin is "full-fitting" in the film perforation; the other is "full-fitting" vertically and undersize horizontally, thus compensating for shrinkage of the film without sacrificing accuracy of registration. So accurate are the movements that a single strip of film may be exposed a multitude of times and yet maintain perfect registration. This exact duplication of registration is assured regardless of the direction of film travel.

To eliminate the possibility of film damage, no pressure is applied to the film during the pull-down cycle. After the film is located on the register pins, and just before the shutter opens, a

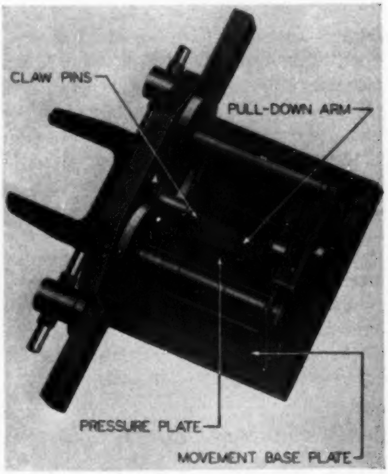


Fig. 2. Intermittent film movement.

small amount of pressure is applied. However, the accuracy of film registration is not dependent upon this pressure. It serves only to hold the film in the focal plane during the exposure.

Engagement of the film perforations on the register pins prior to the exposure and disengagement during the pull-down cycle are performed by the pressure and stripper plates. These plates are made of stainless steel and all surfaces which contact the film are hard-chrome plated for extra protection against scratching.

An especially advantageous feature of the film movement is its ability to accommodate 1, 2 or 3 strips of film and yet maintain perfect registration on all of the strips.

The spring-loaded pressure plate automatically compensates for, and applies equal pressure to, the various numbers of films. This system eliminates manual adjustments of the camera cam when alternating single strip, bipack and tripack methods.

To enable the use of this camera in conjunction with existing studio equipment and procedures, the film movements are supplied with the register pins either above or below the aperture and with the large, or "full-fitting," pin located at any one of the corners of the aperture.

The film movements are easily removed and completely interchangeable within the accuracy of 0.0001 in.; consequently, supplementary movements with the various register-pin locations can be used. This selectivity and interchangeability not only provide film movements which coincide with the optical printer and/or production camera, but will also facilitate and augment the bipack methods presently employed for special-effects and two-color photography.

Printing two-color bipack negatives to the separation positives, and process shots from these positives, best exemplifies the feasibility of supplementary movements. Because of film shrinkage and inaccuracies of the perforations, it is essential, for good quality image, to register consistently with the same "full-fitting" perforation as well as the same pair of perforations as are used for the original negative.

As is well known to users of bipack photographic methods, when the two films are simultaneously exposed in the emulsion-to-emulsion superimposed manner, the "full-fitting" register pin locations of the two records are opposite from right to left in relation to the emulsion and image. Orienting the registration perforations of the bipack negatives for contact printing the separation positives and subsequent process shots, therefore, requires a supplementary movement which will conform to the "full-fitting" perforations of the panchromatic record, when its emulsion-to-light source relationship is necessarily reversed from that of the original exposure. The orthochromatic record, which is exposed through the film base, and therefore retains the same emulsion-to-light source relationship, requires registration locations identical to, i.e., the same movement as, that used for the original exposure.

Step-printing the bipack negatives to duplitized positive stock is equivalent to printing separation positives and also requires two film movements with reverse registration locations.

Figure 3 illustrates the locations of the register pins and the left-to-right image relation of three-color, three-strip negatives. Again, as in two-color, the locations of the "full-fitting" perforations are reversed due to the emulsion-to-emulsion operation of the red and blue records. At the lower part of the figure, the three records are viewed from the emulsion side and it may be seen that the registration perforations of the blue and green records correspond, and the red record is dissimilar.

To prevent deterioration of image quality, the three-strip positives are printed in the emulsion-to-emulsion

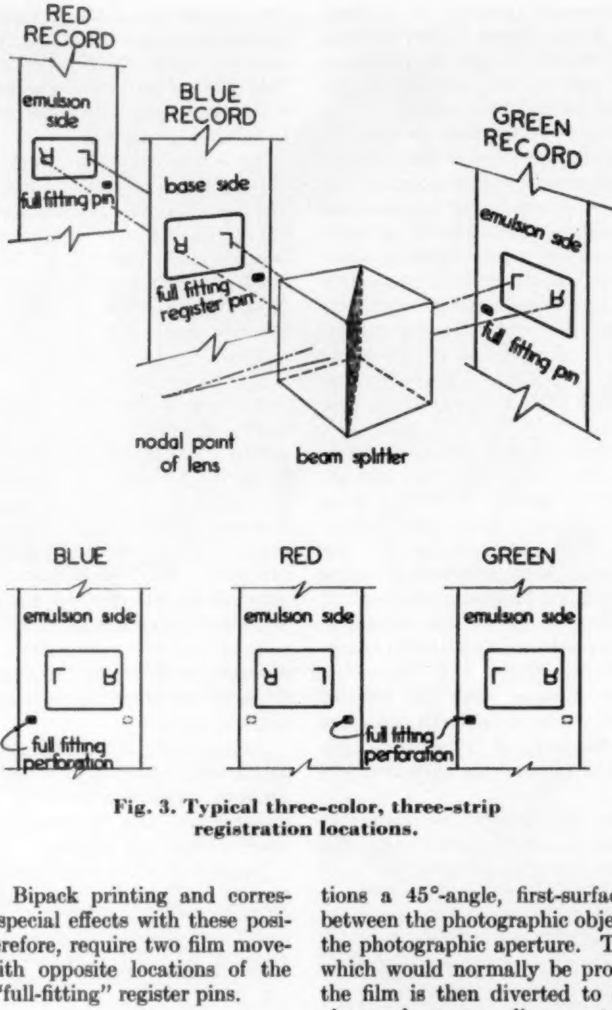


Fig. 3. Typical three-color, three-strip registration locations.

manner. Bipack printing and corresponding special effects with these positives, therefore, require two film movements with opposite locations of the large or "full-fitting" register pins.

Viewer

The viewing device is of the positive reflex type which enables the operator to view the image produced by the photographic objective without the necessity of shifting or "racking over" the camera.

A lever is located on the face of the camera which, when actuated, positions a 45°-angle, first-surface mirror between the photographic objective and the photographic aperture. The image which would normally be produced on the film is then diverted to a ground glass and corresponding aperture in the viewer. This image of the objective scene, as observed through the viewing tube, is magnified approximately two times and is erect and correct from left to right.

A safety device prevents the camera-drive motor from operating while the viewer is employed.

Also embodied within the viewer are

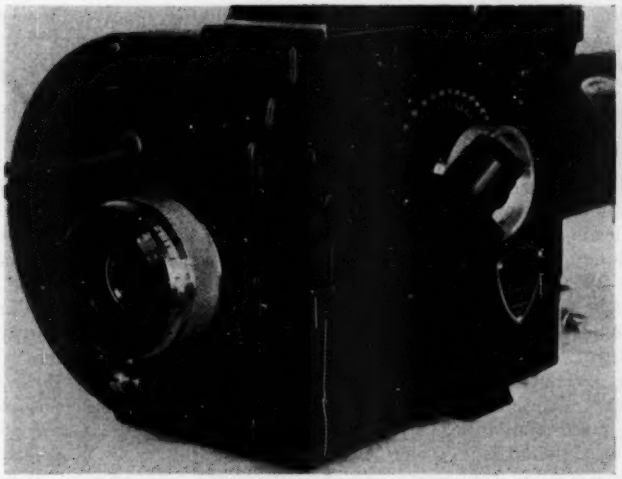


Fig. 4. Three-quarter front view of camera showing processed stock located on the register pins of the viewer for obtaining a composite or matte-shot view.

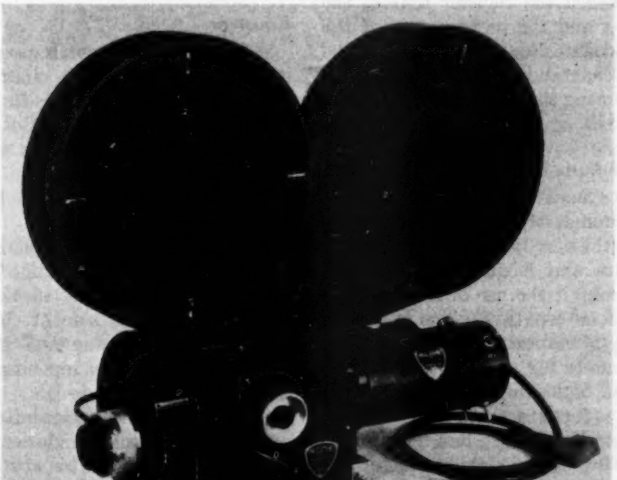


Fig. 5. Side view of camera with lamphouse attached.

two register pins which are in exact optical alignment with the register pins of the movement. By placing a piece of processed stock on the register pins of the viewer (Fig. 4), a matte-shot view or a compositive view of the objective scene is obtained, thus assuring exact composite alignment and registration during future printing operations.

The viewing tube may be removed and a lamphouse substituted for it (Fig. 5). This arrangement allows processed stock to be located on the register pins of the viewer and its image projected through the photographic objective. From this projected image, a matte may then be painted. This method of matte-shot projection does not expose the raw stock threaded in the camera. When the viewer release button is pressed, the reflex mirror retracts and allows the painted matte to be photographed.

Because of the exact optical alignment between the register pins of the movement and the register pins of the viewer, composite alignment of the original scene and of the matte shot is assured during the bipack printing operation.

Lens and Lens Mount

The lens is a 75-Mm Ektar Enlarging Lens, although other lenses varying in focal lengths may be utilized.

The size and location of the reflex viewer prohibit the use of lenses of the "shorter focal lengths." The minimum focal length adaptable to the camera is approximately 62 mm, although this varies and is dependent upon the particular lens formula.

Focusing is accomplished by rotating the focusing ring in the conventional manner. To prevent an "image shift," due to the lack of a common optical axis, the lens barrel and elements slide along the optical axis but do not rotate.

The focusing ring index is graduated for both single-strip and bipack focusing. The bipack index compensates for the variation of the focal plane when photographing through the film base.

Color Wheel

Built in between the aperture and the lens is a color wheel that contains the necessary neutral density and color filters for three-color, successive-frame photography.

This color wheel rotates synchronously with the camera shutter and places, in sequence, the blue, red and green filters in front of the film during the three successive-frame exposures.

To convert the camera to black-and-white photography, a lever on the front of the camera case is turned. This retracts the color wheel from its position in front of the film, but does not affect the synchronism between the shutter and the color wheel. Shifting the control lever is the only manipulation required to reconvert the camera to successive-frame color photography.

Counter

A foot and frame counter is provided; its accurate, reversible characteristics facilitate duplication of frames for multiple-exposure shots. Both footage and frames are recorded on one resettable unit.

Adjustable Shutter

The range of shutter opening is adjustable from 0°, or completely closed, to a maximum opening of 170°. The large knob on the side of the camera regulates this opening and it is indicated in degrees of opening by the pointer and graduated scale.

An optional automatic shutter device produces the selective fades of 1-, 2-, 3-, 4- and 8-ft lengths. This attachment is located at the back side of the camera as shown in Fig. 6.

A unique gearing and linkage arrangement closes and opens the shutter at a semilogarithmic differential. That is, when closing, the amount of shutter variation between successive frames

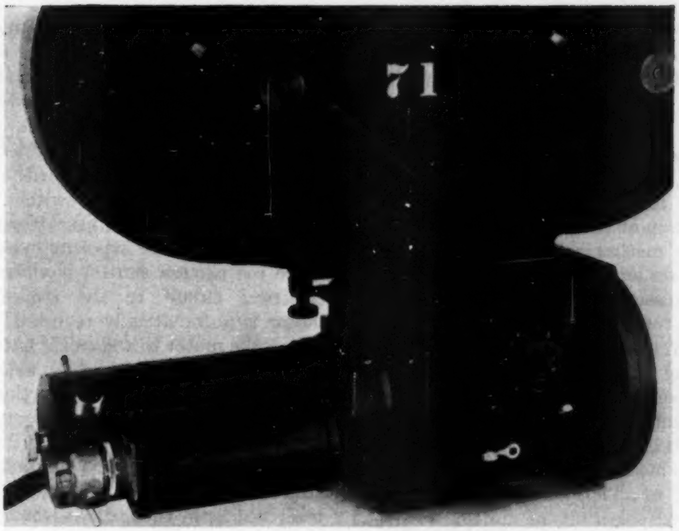


Fig. 6. Back side of camera embodying automatic shutter attachment.

gradually decreases as the shutter approaches the closed position. When opening, the variation operates inversely.

Because this fade operation is based on variations of the percentages of exposure, it will more accurately produce "smooth" lap dissolves wherein the combined densities of the exposures will approach matched densities throughout the dissolve action.

Magazine Drive

Automatic film take-up, both forward and reverse, is accomplished with the magazine drive unit (Fig. 1). This completely gear-driven device eliminates belts, pulleys and manual operations when changing the direction of the film travel.

Located at each magazine spindle is an overriding friction clutch. Its multiple-friction-disk design assures uniform film tension throughout the film roll.

Magazine drives are available for use with either 400-ft or 1000-ft capacity magazines.

For bipack magazines the conventional pulley-and-belt type take-up may be obtained. It is mounted on the camera case in the same manner as the automatic magazine drive and is interchangeable with it.

Buckle-Trip

In the event of take-up failure, a buckle switch automatically stops the camera-drive motor. The buckle-trip arm is dual and is located above the sprocket at both the take-up and take-off side of the film magazine, thereby protecting against take-up failure when the camera is operating in either forward or reverse.

Removal of the film buckle, by manually rotating the magazine spindle, automatically resets the buckle switch and eliminates the necessity of opening the camera door.

Motor-Drive Units

Two types of motor-drive units are available for use with the camera. They are:

1. The stop-motion motor (Fig. 1), for single-frame exposure; and
2. The variable-speed, synchronous drive motor, featuring synchronous operation at various speeds.

The mechanical operations of these units are similar. In both units a gear transmission is located between the motor rotor and the camera-drive shaft. The various speeds are obtained by shifting the gears of this transmission. Because the speed of the motor proper is constant and friction slippage devices have been eliminated, exact speeds are maintained with full motor power delivered at all speeds.

Speed selection, or shifting gears, is accomplished by turning the knurled dial, located at the front of the motor housing, to the desired speed.

The variable-speed, synchronous drive motor delivers the synchronous speeds of 24, 16, 12, 6, 3 or 1.5 frames per second.

The stop-motion motor combines stop-motion action with selective speeds or exposure times. These exposure times are ¼, ½, 1, 2 or 4 seconds in duration; however, an infinite exposure range is possible by regulating the angular opening of the dissolve shutter.

For rewind and title work, a $\frac{1}{16}$-second exposure is provided which operates continuously only; all other speeds operate either continuously or with stop-motion action.

The stop-motion is actuated by a remote, portable pushbutton switch. Each time the switch is pressed the camera makes one exposure.

For three-color, successive-frame, animation photography, a selector switch is provided which changes the ratio to three exposures each time the switch is pressed.

The automatic stopping action of this unit is controlled electrically with microswitches and a centrifugal switch. After the stop-motion unit has driven the camera through the exposure cycle, and while the camera shutter is closed, the electrical circuit to the stop-motion motor is automatically reversed. This brings the motor to a smooth, but quick stop. Prior to its normal action of starting in the opposite direction, the centrifugal switch opens the circuit and the motor remains stopped. Pressing the push-button switch restarts the stop-motion motor in its original direction, which, in turn, drives the camera through the ensuing exposure cycle.

Both the stop-motion motor and variable-speed, synchronous motor operate either forward or reverse. This reversing switch and the other necessary electrical receptacles are embodied in the end-bells of the motor.

A threading knob at the rear of the motor units enables the operator to rotate the motor manually for film loading.

The drive units may be interchanged quickly by removing four screws at the rear of the camera case.

Due to the increasing demand for precision 16-mm process equipment, a 16-mm model process camera has also been constructed. Its design is practically identical to the design of the 35-mm model. Because of the different requirements of 16-mm photography, the color wheel of the 35-mm model is omitted on the 16-mm camera.

Revision of PH22.15 and PH22.16

Formerly Z22.15 and Z22.16

MINOR REVISIONS of two American Standards, Z22.15—1946 and Z22.16—1947 ("Emulsion and Sound Record Positions in Camera for 16-Mm Sound Motion Picture Film" and "Emulsion and Sound Record Positions in Projector for Direct Front Projection of 16-Mm Sound Motion Picture Film"), have been proposed by the Standards Committee. The proposed revisions of the existing Standards appear on the following pages.

Since the designation of the guided edge is not an essential nor a proper part of these Standards, it was proposed that it be eliminated.

In addition, one editorial change has been made in the title of paragraph 2 of each Standard. "Speed of Projection" has been changed in Z22.15 to "Rate of Frame Exposure" and in Z22.16 to "Rate of Frame Projection."

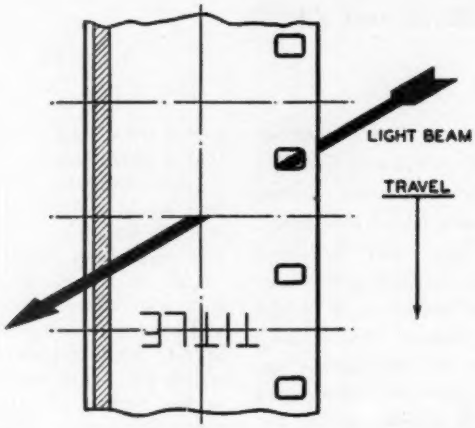
The proposed revisions are published here to invite comments and criticism, within the next ninety days, by members of the Society or others interested in these Standards. Please forward any comments to Henry Kogel, Staff Engineer, at Society Headquarters, by September 1, 1951.

Proposed American Standard

Emulsion and Sound Record Positions in Camera For 16-Millimeter Sound Motion Picture Film

PH22.15
Revision of
Z22.15-1946*

*UDC 778.53



Drawing shows film as seen from inside the camera looking toward the camera lens.

1. Emulsion Position

1.1 The emulsion position in the camera shall be toward the lens, except for special processes.

2. Rate of Frame Exposure

2.1 The speed of projection shall be 24 frames per second.

3. Distance Between Picture and Sound

3.1 The distance between the center of the picture and the corresponding sound shall be 26 frames.

*Elimination of "Guided Edge" is the only revision from the 1946 edition.

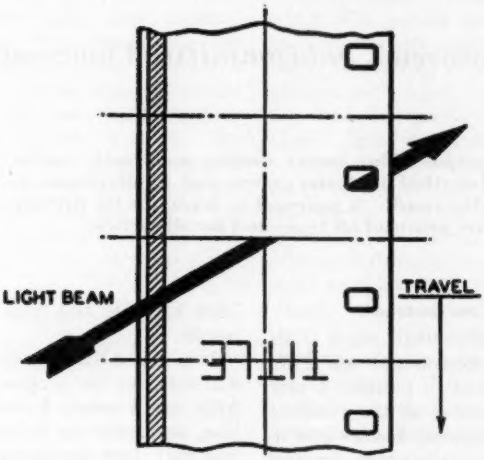
NOT APPROVED

Proposed American Standard

Emulsion and Sound Record Positions in Projector for Direct Front Projection of 16-Millimeter Sound Motion Picture Film

PH22.16

Revision of Z22.16-1947*



Drawing shows film as seen from the light-source in the projector.

1. Emulsion Position

1.1 The emulsion position in the projector shall be toward the lens, except for special processes.

2. Rate of Frame Projection

2.1 The speed of projection shall be 24 frames per second.

3. Distance Between Picture and Sound

3.1 The distance between the center of the picture and the corresponding sound shall be 26 frames.

*Elimination of "Guided Edge" is the only revision from the 1947 edition.

NOT APPROVED

New All-Purpose Film Leader

A Status Report, April 1, 1951, of the Subcommittee on Film Leaders of the Films for Television Committee

By C. L. Townsend, *Subcommittee Chairman*

A new all-purpose film leader design, commonly called "The Society Leader," is described, its history given and its development, tests and uses to date are discussed. A proposal is made for its further application to motion picture prints of all types and for all services.

1. Preliminary Conclusions

In the one and one-half years of its existence the Subcommittee on Film Leaders has worked to produce a new leader design retaining all the excellent features of the Academy Leader now in general use, and providing some features which are highly desirable from the viewpoint of a new and growing user of film productions—television. It is believed that this has been accomplished.

Early in the work a purely television-centered program was abandoned in favor of a broadly applicable design. Since then the leader has been tested by commercial laboratories, professional theater projectionist groups and equipment manufacturers. Careful attention was given to the proposals of each and a gratifying spirit of cooperation and understanding was developed.

The New York offices of several television companies have been using the new leader on their television recording releases and on certain other television films. More than 10,000 prints have been so made and used with excellent results.

It is hoped that all interested persons will consider the proposed leader carefully, use it widely for test and evaluation, and send the Subcommittee their findings. It is the intention that a proposal for standardization shall be made when widespread results warrant it.

2. Features of the New Leader

The present American Standard Z22.55-1947 is the foundation for the new leader design. Only additions have been made, and only such additions as cause no deletion of past features. Under Z22.55, paragraphs (1) and (2) remain unchanged. Paragraph (3) is changed only as to frame content, and paragraphs (4), (5), (6) and (7) are unchanged.

2.1: The main body of the leader ahead of the three-foot mark is changed from a solid black to an appropriate simple pattern (see illustration). The design is intended to be used in television to permit checking system operation before switching into the first picture frame.

Submitted for publication April 27, 1951.

The basis of the pattern is familiar to most television engineers. A neutral gray background provides a foundation for the pattern proper, which consists of two concentric circles having diameters in the ratio of 4:3, and four arrows whose tips establish the limits of scanning as defined by the SMPTE Television Test Reel.

Approximately equal areas of black and white are used to provide reference levels for video gains and pedestal settings. These two limits, together with the background gray, provide a rough check of system transfer characteristic, since the gray value used is approximately centered between the black and white tones. Experience will indicate where the gray level should fall on the wave-form monitor when the system provides best reproduction. The assigned density values of these areas are:

White	0.2 ± 0.1
Gray	1.0 approximately
Black	2.0 ± 0.2

The pattern also provides a secondary indication of scanning adjustment and camera-projector alignment. This will greatly reduce the need for "blind" switching; that is, for switching into a film sequence from equipment having only accidental scanning control settings.

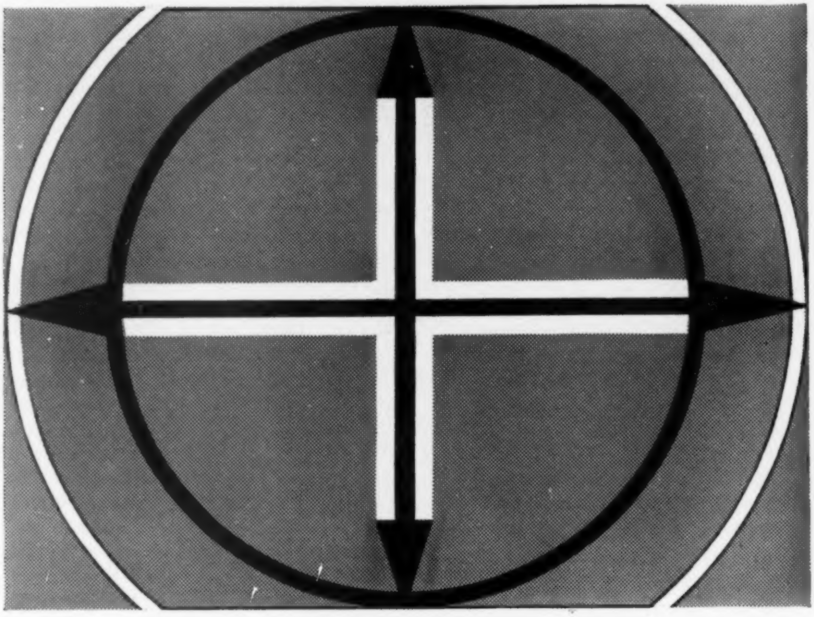
Much of the above information can be gained during the rolling time of a normally threaded leader. In addition, when stop-frame projection is available (its use is rapidly increasing), the projected pattern permits advance check of the entire electrical system, including effects of beam current, edge-light, back-light, etc. Also, the presence of the "average video" information between cue numbers reduces the tendency of the system to "bounce" as the cues go by.

2.2: The footage numerals have been changed to project right side up. It has been found that precise television program switching has caused these numerals to become of great value to program directors. They can count to their first-frame cue from the rhythm set by the passing numerals, resulting in excellent switching accuracy. Right-side-up projection makes them easier to read for this service. To prevent errors of reading by both production directors and projectionists the "SIX" and "NINE" markers are spelled out.

2.3: The picture threading frame for each 35-mm foot is identical with the old leader, consisting of a full white background with black numerals overlaid. No threading problems are introduced there. However, a single frame, when projected, does not have enough visual effect to permit positive recognition of the numeral; therefore, each numeral is repeated one frame before and one frame after each threading frame, but with the outer portions of the main target design added. As seen in the illustration, there is no possibility of confusing the threading frame with those added for visual effect. This permits normal threading procedures used in theater projection to continue without modification.

2.4: The 35-mm sound threading marks have been changed to read in plain English "35 Sound," replacing the previously used diamond mark. No explanation of function is necessary, therefore, for persons unfamiliar with the use of a leader, as was the case before this change. The lettering used is right-side up to the projectionist, and on the side of the film occupied by the sound track. No change in threading procedure is required.

2.5: 16-Mm sound threading marks have been added to define the sound scanning position for that service. As in the 35-mm case, the sound mark reads in plain English and occurs on the side of the film next to the sound track. The leader can thus be used for both reduction printing and contact work without change.



Main Body Pattern.

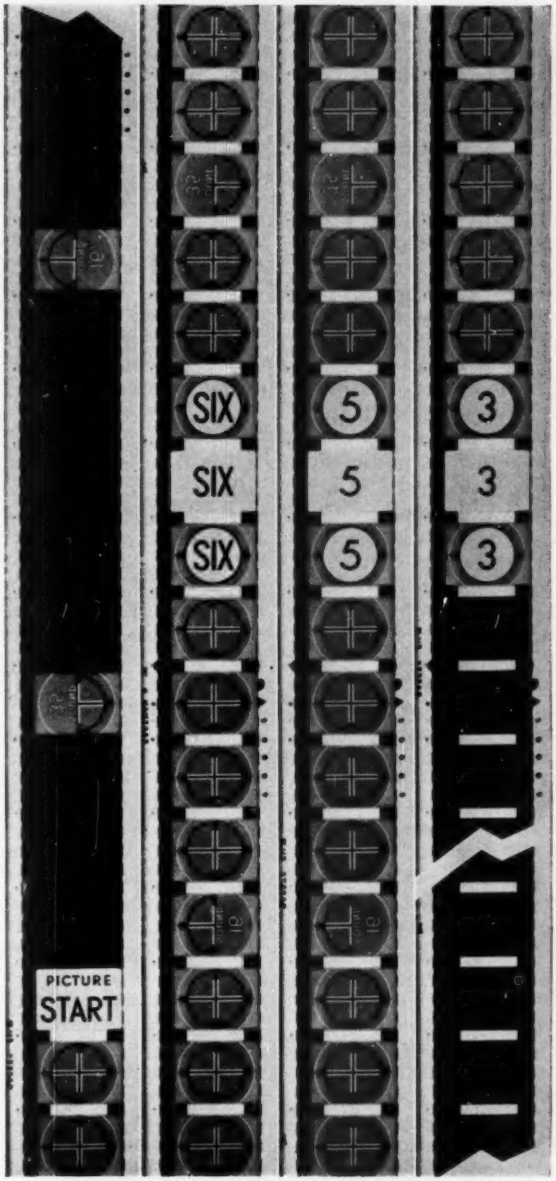
Previously no indication was provided of proper threading for 16-mm use. Yet it has been found that most projectors can be misthreaded. Past practice, in cases of controversy, has been to count 26 frames and mark the sound position with grease pencil. No problems of this sort need occur with the new leader. Of course, the presence of an indication of correct threading position also increases the precision of ordinary operation.

2.6: The black frames following the three-foot marker are slightly changed to a dark gray. The tone value is not altered enough to affect theater projection, but will permit television operations to switch into the dark frames without as much "flare" and "black-spot" as now occur. No change in theater practice is required.

The density value used for these frames is approximately 1.6 but may vary somewhat, depending upon printing conditions. In general, the intention is to provide some iconoscope plate illumination to stabilize its operation.

2.7: A small switching cue (see illustration, third frame above lower right-hand corner) has been added in the eighth dark frame before the first frame of picture. The cue is the standard mark used for change-overs but confined to one frame. It is to be used as an indication to television directors that the picture will start within normal switching reaction time. Since the cue is very small, occurs only on one frame, and is on a part of the film not normally shown in theaters, it will not affect theater practice in any way.

The switching cue also gives a clear indication to a cutter when a particular leader has been used too often, resulting in excessive loss of frames due to splicing. A few frames can be lost without serious consequences, but when their



Sample Footage From Proposed Leader.

Read from the upper left to the lower right; broken edges indicate duplicate frames deleted.

number exceeds four or five, that leader should not be re-used.

2.8: Reel identification standards have not been changed. It is worth noting, however, that nonstandard practices have grown up, particularly in television film-making. American Standard Z22.55–1947 defines proper procedures and should be followed rigorously. The proposed leader is carefully designed to supply needed information throughout its active length. It should not be mutilated by slates or special markings in any position other than the standard allows or its usefulness will be greatly impaired.

3. Evaluation

3.1: Any new thing is strange at first, inevitably. Every effort has been made to reduce this strangeness by retaining unimpaired the previous functions of the leader. But each new function has introduced some new appearance. It is suggested that evaluation be a slow process, with time for all to become familiar with the entire content of the leader. In this way the information in it which is not pertinent to the particular use can be ignored and full attention can be given to the useful cues.

For instance, suppose a production director is primarily interested in the footage cues. He may at first see the sound cues too clearly, but once they have become familiar, and he knows they are of no importance to him, they will recede in visual impact and become completely unnoticed.

Again, a theater projectionist may be primarily interested in the threading cues and feel that the television pattern is confusing; but once he thoroughly understands the pattern, it is of no interest and so diminishes in importance, permitting the useful cues to emerge. Whenever a little time has been allowed for this phenomenon to take place, no permanent objections have been registered.

3.2: Some feeling has been expressed that the leader is "hard to print." As compared with the dupe of a dupe of a dupe sometimes used for the old leader, it is somewhat more difficult. But any good laboratory can do a thoroughly acceptable job without difficulty, and the result is good dressing for a fine printing job.

4. History and Development

In January of 1950, F. T. Bowditch, the Society's Engineering Vice-President, decided that the information which had been submitted to him on present leader deficiencies warranted an investigation. The project was assigned to Dr. R. L. Garman's Subcommittee of the Engineering Committee on Television, and it in turn assigned it to a Subcommittee under C. L. Townsend. When the engineering activities of the Society in television fields were reorganized and expanded a few months later, the project was transferred to the new Committee on Films for Television, with the Leader Subcommittee reporting to that group. It held its first meeting on February 17, 1950.

At first there was some feeling that a special television leader might be produced which would exist as a special-service standard and leave unmodified the old Academy Leader. At that time major design changes were considered, including 24-frame spacing for the threading cues. However, after long debate by representatives of laboratories and projectionists, it was decided that the problems of dual-purpose release (including reduction printing) and the confusion always resulting from dual standards could be avoided by a proper common-use leader design. Thereafter all the efforts of the Subcommittee were directed toward the production of a leader to fit this policy.

From the beginning excellent cooperation was obtained from producers, laboratories, projectionists and broadcasters, resulting in the issuance on April

19, 1950, of the first sample leader (in card form) for limited comment and criticism. Some two months later these comments were embodied in the first sample leader film intended for actual test use. It was then discovered that the projected visual impact of the footage cues was insufficient to permit good cuing, so the two additional cue frames were added, and that version of the leader was tested with good results.

The September 8 meeting of the Subcommittee requested authority for more widespread testing of the leader. Having received that permission, samples were sent to many organizations not represented on the Subcommittee itself. Again the reactions were reasonably approving, except that the Motion Picture Research Council objected on the grounds that the leader would work an undue hardship on theater projectionists.

In order to obtain the reactions of professional theater projectionists to the proposed leader, the services of the Projectionists' Union were enlisted. After several weeks of consideration an enthusiastic report was received from Steve D'Inzillo, the Union's Business Representative.

Other meetings considered and adopted or rejected proposals received until on March 22, 1951, the Subcommittee decided that the foundations for the new leader had been well established, that the time had come to request that it be publicized to the fullest, with the broadest sort of operational and functional test, directed toward the writing of an official standard. This Status Report is intended to be the first step in that direction.

5. The Next Steps

When and if the parent Committee decides that the above extensive test may be undertaken, the Subcommittee will canvass by letter the television film producers and advertising agencies, requesting that the new leader be used on their special releases. It is hoped, also, that the major feature film producers will cooperate in the test. Certainly in this way all possibilities can be explored and all answers firmly given.

The Subcommittee

Charles L. Townsend, *Chairman*
V. D. Armstrong
R. O. Bigwood
L. W. Davee
T. P. Dewhirst
L. B. Gumbinner
C. F. Horstman
H. R. Lipman
K. E. MacIlvain
K. E. Mullenger
J. G. Stott
C. A. Younger

Note: At a meeting held on May 2, 1951, the parent Committee voted permission for the Subcommittee to conduct the test mentioned above.

Progress Committee Report

Progress in the motion picture studios during 1950 was highlighted by the advances in various color systems and the apparent acceptance of color for pictures of all classes and types. The taking speed of the Technicolor system has been increased considerably. Several laboratories within the studios, or serving the studios, have been remodeled to handle the various other color systems which are now in active use.

The drive for production economies continues and a number of different things have been tried with varying success. During 1950 radio communication facilities were used extensively between studios and location units, as well as for the control of production personnel and equipment. The FCC allocated radio channels to the motion picture industry specifically for this purpose. Closer pre-picture planning among the production groups resulting in the reduction of shooting-days per picture has probably been the greatest money-saving factor.

In picture and sound reproduction the work of the Screen Brightness Committee has created a great deal of interest among studio personnel and the results of the 100-theater survey promise to bring about a better relationship between negative density, print density and average projection light.

The various television broadcasters are continuing with the policy of moving into studios where space limitation is not such a serious factor.

Submitted, April 13, 1951.

The use of motion films in television has grown steadily throughout the year. Already a considerable number of shows are being filmed and there are indications that the majority of the sponsored shows may eventually be broadcast from film. Much of this shooting is being done by independent producers, but with increased studio space some television companies are preparing to film their own productions.

The Zenith Phonevision system has been undergoing a consumer test with the permission of the Federal Communications Commission. These tests have used 35-mm films produced for theatrical release. The prints have been regular color releases, or regular black-and-white releases, as well as special black-and-white prints made to Zenith's specifications of density and contrast.

35-Mm Photography

By July of 1950 conversion to safety film was approximately 85% complete. It was stated that Eastman had discontinued the manufacture of 35-mm nitrate positive film for motion pictures Some Eastman safety stock is being used by Du Pont pending production of a suitable safety stock by that company.[1]

The studios are showing more and more interest in traveling matte techniques and considerable work has been done with them, particularly on color.[2]

Color Processes. The Eastman 35-mm negative-positive color process which was introduced experimentally in 1949

has now been used in a number of full-length pictures.[3]

One studio is shooting pictures with Eastman color negative, viewing dailies on Eastman color positive, and will release on SUPERcineCOLOR three-color print stock.[4]

A second studio has made a feature picture on Eastman color negative and will release on Du Pont color print stock.[5,6]

Another studio is shooting a feature picture on Ansco negative-positive and is doing all of the processing in the studio.

Other studios are preparing to produce some of their own color films by any one or more of the afore-mentioned processes, or by shooting on black-and-white stripping film and using the three-color separations for printing on any one of the print stocks.[7]

In France the Gevacolor process is now reported available for release prints. Three full-length features in Gevacolor were produced in France during 1950.

In laboratories in the color field, the Cinecolor Corporation reports the following:

(1) Installation of equipment and production processing of the Eastman color negative film.

(2) Installation of equipment and production processing of the Eastman color positive film (with sound).

(3) Full scale conversion for the SUPERcineCOLOR three-color release printing.[4]

(4) Establishment of the Cinecolor two-color process in Great Britain.

Consolidated Film Industries has equipped both its Fort Lee and Hollywood laboratories for production of "Trucolor." The company is now in release production of the new three-color Trucolor prints. The print stock is Du Pont three-color material type 875 and the original negative is the Eastman Kodak automatic masking three-color film type 5247.

The sequential operations are: three separation prints on panchromatic film from the color negative, three duplicate negatives optical effects incorporated, on gray base stock through selective filters from these prints which are then printed through proper filters for layer selectivity, on the multiple layer Du Pont print stock.[6]

It has been announced that the Du-Art Laboratories in New York will make "Tri-Art" color on Eastman, Ansco and Du Pont color materials.

Technicolor has announced and is at present working with films for the three-strip cameras which are balanced for a color temperature of approximately 3350 K. It is claimed that this system will bring illumination requirements within the range of that now used for black-and-white photography. It was announced that the system will be available for general use within a few months.[8,9,10]

Lighting Equipment and Techniques. Technicolor announced a change in color balance of the three-strip system from that of sunlight to a color temperature of approximately 3350 K. This resulted in the production of gelatin-type filters for the carbon-arc lamps to reduce their color temperature sufficiently for them to operate in conjunction with unfiltered tungsten lamps.

This change is at present in the transition stage. Some time ago the Technicolor system was increased in speed by a ratio between 450 ft-c and 300 ft-c key-light on a white light, or sunlight, basis. Later, by going to a 3350 K basis a further increase in speed to 150 ft-c was announced. This latter increase in speed is, however, applicable only to incandescent tungsten lamps because it is necessary to filter the high-intensity carbon arcs by approximately the amount gained in order to provide a color balance.

At the time of completion of this report only tests and picture sequences

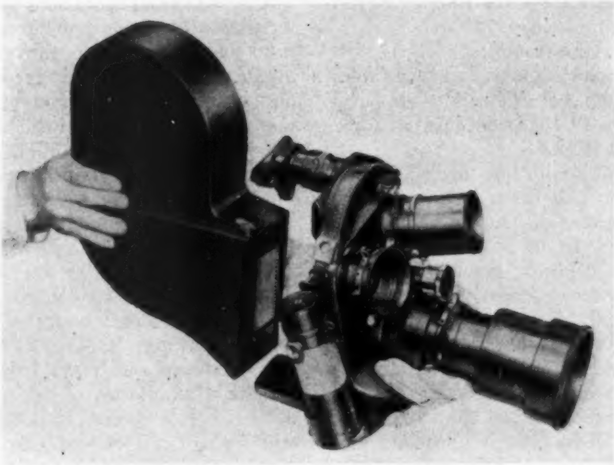


Fig. 1. Eclair "Cameflex" takes 35-mm and 16-mm film interchangeably by changing film magazines.

have been completed with the 150-ft-c system balanced for 3350 K. Productions have been made with the 300-ft-c white light system.[8-11]

In France the Bréguet Company has brought out a new 150-amp automatic carbon-arc lamp for stage lighting which has received considerable notice because of its stability.

While no mercury-cadmium lamps are in present use for set lighting in the West Coast studios, the bulbs are available and are being evaluated by the Research Council.[2]

Reflector-type incandescent bulbs such as photoflood and photospot lamps have been increasingly used on location where the documentary type of lighting is indicated and for nontheatrical releases.[2,12,13,14]

Cameras and Accessories. A system for special effect shots has been devised and applied at present to panning and tilting the camera, which permits the cameraman to pan and tilt the camera in a normal manner and follow the action as desired. A record is made of the movement and, for subsequent exposures on the same film, the record controls the camera movement, matching the original relation between the camera position and picture frame during these subsequent shots.[15]

In France two new lenses were announced. "Retrofocus," a very short focus lens designed so as to permit attachment and use on normal 35-mm cameras, and "Erax," a highly corrected lens developed by Société Kinoptik in which the graduation of the aperture of the diaphragm is proportional.

The Eclair Camerette, introduced in the United States from France in 1949, now has a companion model, the "Cameflex," which takes 35-mm and 16-mm film interchangeably (Fig. 1).[16,17]

The "Aquaflex," shown in Fig. 2, was introduced in the United States in 1950, the first one being used by the United States Navy. Essentially, it is a standard 35-mm Camerette with a specially designed magazine in an underwater blimp which permits external stopping and starting, speed control, focus and diaphragm changes.

A compressed-air cylinder attached to the underwater housing, working on a demand valve, maintains an internal pressure of 3 psi above the external pressure, irrespective of the depth to which the camera is submerged. Stabilizing fins allow the camera to be moved through the water smoothly. The camera and housing weigh about 100 lb when out of the water. Great flexibility of operation is attained by using diving equipment with self-contained air supply for the operator. While propelling himself and the camera by means of swim fins attached to his feet, the cameraman, unaided, can maneuver the camera and operate aperture and focus controls. Smooth travel shots, following divers or native fish down to a depth of 80 ft, have been shown before the Society.[16]

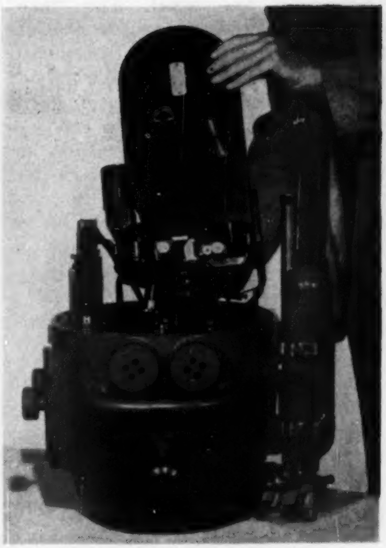


Fig. 2. The Aquaflex underwater photographic unit.

35-Mm Sound Recording

The year 1950 has seen noteworthy progress in the application of magnetic recording to motion picture production. The extent of the application has varied among the producers from cautious planning and preliminary experimentation, with the view of future conversion, to complete conversion to magnetic recording on all production and music recording work.

While many advantages with respect to quality of production, maintenance and operation of equipment, and conservation of film raw stock accrue from the use of magnetic recording, the over-all recording operation, from the original recording of dialogue and music to the production of the final release print, has been considerably complicated. As a result, many of the extensive claims of great economies to be effected by the use of magnetic recording have been considerably modified and conversion programs are now more in the nature of plant modernization. The great demand for smaller and lighter portable equipment for location, has been, possibly, the strongest influence in affecting the choice of magnetic recording, as magnetic-recording equipment has been the answer to this problem.

Since April 1, 1950, all Paramount production, both in the studio and on distant location, has been done on super-portable recording channels, weighing 65 lb and using 17½-mil recording stock[18] (Fig. 3).

New portable magnetic-recording systems for 35-mm, 17½-mm or 16-mm film, featuring compact, light weight construction, were introduced by Westrex, and are now in wide use in studios both here and abroad[19] (Fig. 4).

The use of magnetic equipment and re-recording has gained momentum. It has become the practice in a number of studios to record rehearsals on magnetic film. A good "rehearsal" becomes a "take" and unsatisfactory

"rehearsals" are erased. The "take" can be reviewed at any convenient time and then transferred to photographic film for release printing. In this connection, a multitrack magnetic equipment has been used to good advantage. This equipment records one, two or three tracks on the same film strip on which music, speech or sound effects, or any combination thereof, can be recorded with the same relative volume variations as they have in the finished product (Fig. 5). The benefits of this equipment, as experienced by Columbia Studios, are as follows:

It saves track storage space by a factor of about 10 to 1.

It reduces the cost of foreign versions by 50%.

It provides a ready means of furnishing duplicate release negatives as needed.

It provides a convenient source of material for television versions "minus music" and it provides a source from which dialogue, music and effects can be rebalanced in the dubbing of 16-mm versions.

Fig. 3. The Ryder portable magnetic sound recording unit.

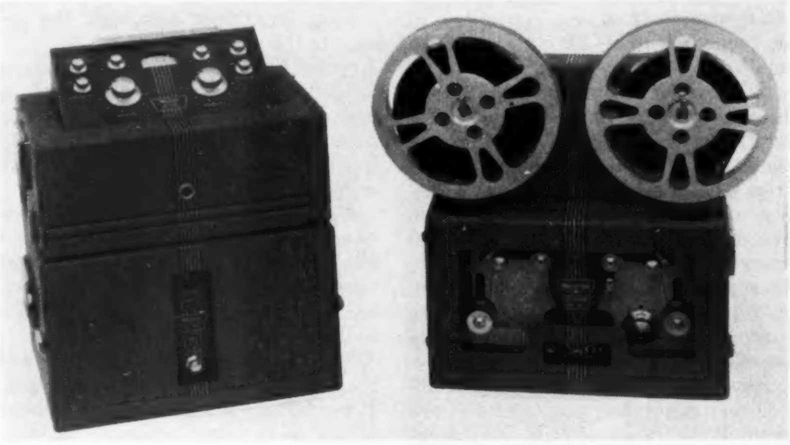


Fig. 4. Westrex portable magnetic sound recording system.

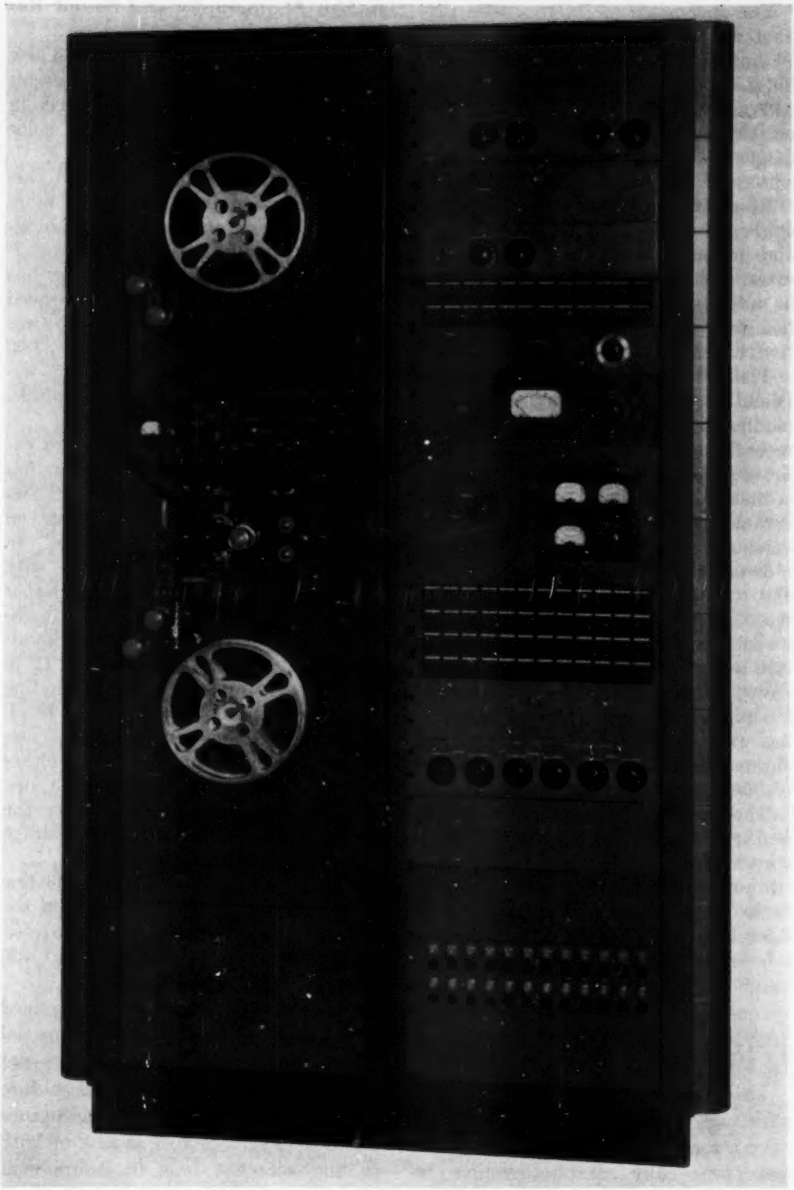


Fig. 5. RCA 35-mm 3-track magnetic recorder.

The increased use of magnetic production recording, together with a lack of suitable means of editing this material, has resulted in the development and use of equipment to make direct-positive photographic duplicates of the magnetic recordings for use by film editors.

Re-recording is being done in some studios directly from magnetic tracks, and in some, from photographic duplicates. Photographic duplicates may be either direct positives or electrical transfers to a photographic negative from which re-recording prints are made.

The Signal Corps Studios, Long Island City, N.Y., have applied several modifications to standard magnetic recording systems, which provide improved operating efficiency as well as economies in time and material. These include facilities for: (1) stopping, reversing and restarting recorder, re-recorder and projector in interlock, and (2) silently changing over from record to playback, or vice versa, while running. Thus, errors in narration and re-recording jobs may be corrected without rethreading, splicing or blooping the film. Also, this studio has perfected a method for lip-synchronous production which makes use of 35-mm magnetic loops.[20]

The year 1950 has seen continued and extended use of nonsynchronous sprocketless-type magnetic recording equipments, particularly in the field of radio transcription. There have been described in the JOURNAL a number of schemes that have been developed to make these equipments operate synchronously with picture film for use in television and for cue-track recording.[21,22,23]

Last year also saw the use of low-shrinkage safety-base film extended to sound recording. By the end of the year practically all photographic recording was being done on acetate-base stock.

16-Mm Photography and Sound Recording

Ansco has placed on the market a new 16-mm color duplicating film. Ansco's new film type 238 is designed for making duplicates with soft gradation color originals.[24]

The JOURNAL for January 1951 carries a complete bibliography of more than 600 items on high-speed photography covering all phases of the work.[25]

The Naval Ordnance Laboratory has developed techniques in the high-speed photography of underwater explosions. Pictures ranging from 2,000 to 3,000 frames/sec have been made of explosions of charges up to 1 lb, at depths down to 2 miles.[26]

Early in 1950 a new 100-ft-film capacity, 16-mm single-system sound-recording camera called the "Cine-Voice" was introduced by the Auricon Division of Berndt-Bach, Inc., of Hollywood, Calif. It is available with a galvanometer for recording either variable-area or variable-density high-fidelity sound track to SMPTE Standards. The camera weighs only 12 lb and the entire equipment, including amplifier, microphone, cable, headphones, accessories and carrying case, weighs 34 lb. It operates from either constant speed or synchronous motors. A portable power supply to drive the camera from an ordinary 6-volt storage battery is also available.[27]

Film phonographs embodying the fine motion and wide range inherent in the new magnetic recorders were provided for studio re-recording, dubbing and certain television applications.

Magnetic ¼-in. tape recorders gained popularity for many types of industrial and commercial purposes but were not generally accepted for motion picture recording. This lack of acceptance was due to such factors as lack of faith in the sprocket hole to insure synchronization, desire for standard speeds and desire for film that could be run

on existing playback and editing equipment.

The RCA type RT-11A magnetic tape recorder was built for professional service and is being used widely in the broadcasting and television fields. It has also found limited acceptance in motion pictures for recording projection takes.

Comparatively little use was made of 16-mm magnetic film although recorders were available.

Reeves Soundcraft Corp. introduced a service for edge-coating 16-mm raw stock or developed film with magnetic material to permit the use of magnetic sound tracks with 16-mm prints. Excellent sound reproduction from such prints was demonstrated at the fall convention using a modified projector.

J. A. Maurer, Inc., demonstrated a new multiple-track 16-mm sound-recording system that reduces distortion resulting from nonuniformity of the projector sound-scanning light beams.

The Magnagram Corp. of North Hollywood, Calif., has announced a new subminiature field unit, the F-102 magnetic film recorder. Available in 16 mm or 17½ mm, the unit is light in weight (38 lb for two cases) and extremely compact. Film capacity for either is 400 to 1200 ft of magnetic stock.

35-Mm Picture and Sound Reproduction

The activities of the Screen Brightness Committee in obtaining accurate information on a group of 100 theaters throughout the country has already had an effect on the motion picture studio laboratories where the preliminary information is being used to determine if changes should be made in print density.

In at least one studio it was found desirable to increase set lighting levels slightly in order to improve the projection quality of the prints.

This work promises to bring about a much better correlation between production and exhibition both as to print quality and projection conditions.[28,29]

At least two new mirror-type carbon-arc projection lamps have been described. These units feature fast optics, arc-positioning devices, forced air control of exhaust gases and new methods of automatic arc control.[30,31,32]

In the field of control of heat in the projection optical train, there have been a number of installations of units with heat-absorbing glass filters and others with compressed air blowing against the film. In addition, considerable work is being done experimentally and in field tests with treated mirrors and optical train filters of the interference type.[33]

A new all-plastic screen made of Firestone "Velon" plastic and known as RCA Snowhite Evenlite vinyl screen is illustrated in Fig. 6. The material is 0.012 in. thick, weighs ⅙ psi and is said to be sag proof. It is pigmented with titanium dioxide and surface embossed for high efficiency and diffusion. It is also flameproof, mildew proof and unaffected by heat, cold or moisture. The surface is rugged and can be cleaned by washing, soft brush or vacuum cleaner.

A new Walker high-intensity screen is made of plastic in which no vinyl is used. The metallized surface is made up of elliptical forms which spread the light fanwise to control reflection. It is recommended for theaters with wide-angle viewing conditions, but with no more than a 12-deg projection angle. It is claimed that the control of stray light improves contrasts and results in better apparent definition.

Cinerama, a system of exhibiting three frames of film in a curved panorama, has been demonstrated. It is stated that, while the inventor does not claim stereoscopic results from a strictly technical standpoint, the effect is one of super reality. The system includes the use of several sound tracks for projection of stereophonic sound.[34]

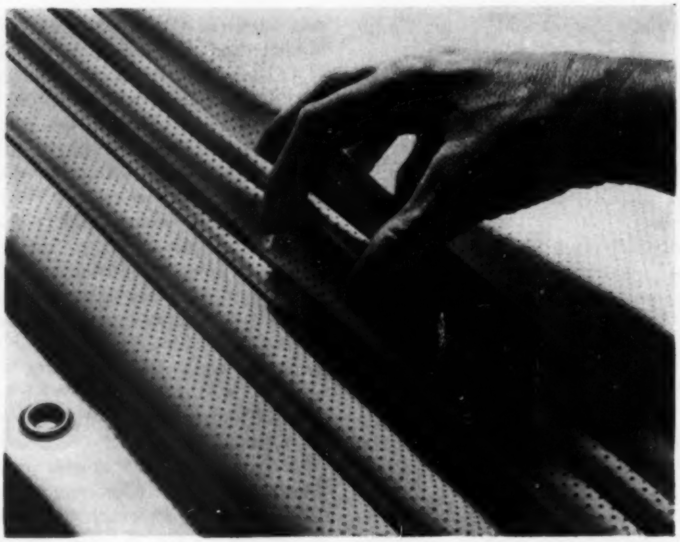


Fig. 6. RCA Snowhite Evenlite vinyl screen.

16-Mm Picture and Sound Reproduction

Nineteen-fifty has been a year of marked improvement in the whole 16-mm process, inspired mainly by television. A number of professional-type 16-mm projectors have been made available, with performance approaching 35-mm standards.

Eastman Kodak Co. has announced and demonstrated a heavy-duty 16-mm professional projector which uses the same type of intermittent sprocket movement as in 35-mm professional projectors.[35,36] (Fig 7).

The International Projector Corp. has described a sturdy, high-quality 16-mm projector designed to meet U.S. Navy Bureau of Ships Specification CS-P-41A.[37]

Mitchell Camera Corp. announced a new "giant" 16-mm professional projector which offers optional high-intensity carbon arc or incandescent lamp illumination. It was designed to function with standard 35-mm sound equipment.[38]

Approximately 1,400 16-mm sound motion picture projectors, built to comply with the high performance required by the Joint Army-Navy Specification JAN-P-49, were put into service by the armed forces during the past year. The Navy Motion Picture Film Exchange, Naval Shipyard, Brooklyn, is employing these projectors to evaluate and accept all 16-mm prints of entertainment films procured by the Navy. The projectors are used in accordance with the Society's "Tentative Recommendations for 16-Mm Review Rooms and Reproducing Equipment."[39] The prints are screened with both lead sulfide- and caesium-type photoelectric cells to insure that there will be no material difference in sound reproduction when the prints are presented to the Fleet on either type of equipment.[40]

Television

Many people have said that television came of age in 1950. There is considerable truth in this statement and it may be traced largely to the fact that the industrial companies of America have recognized television's tremendous sales appeal and have consequently devoted large sums of money to the production of shows intended for release in many cities throughout the nation. Fortunately it has been possible to cover many of these cities, and consequently a large percentage of the television audience, with live programming via the facilities of the American Telephone and Telegraph Co. The so-called nonconnected cities are still covered by the use of video recordings, the quality of which has improved drastically during the year.

The availability of higher budgets has allowed the television networks and studios to use more care in production techniques and staging. Notable improvements have resulted, for example, in lighting, costuming and make-up, the use of process screens, and in a

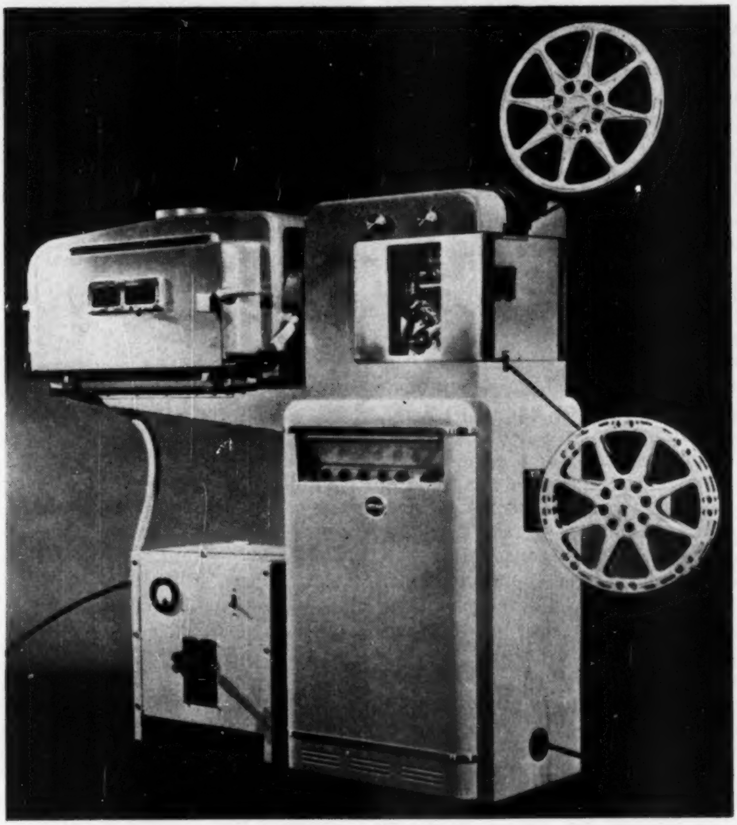


Fig. 7. Eastman 16-mm projector, model 25, with arc lamp.

general recognition of how the limitations of the system must always be carefully considered in the staging of a studio production.[41–46]

The motion picture industry's many techniques, developed over a period of years, are now being used more and more in television studios, although it has been found that these motion picture techniques must be applied with extreme care because of the differences between the mediums.

The marked change in television delineated above has required a great expansion of many of the television stations and studios throughout the country. There seems to be a trend toward more and more space and the industry has concluded that facilities at least approaching in size those of the motion picture production lot will ultimately be required. There have been several purchases of large acreages on which numerous buildings will operate in order to handle the production requirements which are foreseen.

The Use of Film. Direct photography for television shows has increased during the year. A number of production companies have operated specifically for this purpose and with considerable success. Most such productions have been of half-hour shows, some of which have been serialized. Both 16-mm and 35-mm cameras have been employed, although the trend at the moment seems to be the favor of the latter, in spite of the fact that many of the television stations are forced later to use 16-mm reduction prints. Of the top TV network shows on the air at the close of 1950, approximately 20% were on film.[47–50] As recorded in the Progress Report for 1949, there has been some interest in the technique of so-called simultaneous filming of live television shows; however, this technique is still not widely used.

The demand for special prints reflects the growing practice in the television industry. Most large stations on television networks have established standards for print characteristics which give optimum television quality.[51]

Background projection as an adjunct to live programming is becoming more common.

The technique of film projection for television transmission has received a lot of study. A method of improving the image quality by using filters in the projector to remove infrared radiation, and by filtering edge- and bias-light in iconoscope film cameras has been proposed. As a result of the interfering effects of light level and tube variation, this procedure is still controversial.

The Eastman Kodak Co. has manufactured a new 16-mm television projector, model 250, which is intended to give superior performance for film chains. The projector operates on the conventional 5% application principle, but offers improved picture steadiness, brightness and definition as well as excellent sound quality. Facilities are provided for continuous projection of a single frame, or regular projection with remote operation (Fig. 8).

Video Recording. Video recording progress during 1950 has been very great. In fact, it is generally agreed among those intimately involved with this technique that within the limits of the television system as established by the FCC and as further laid down by equipment limitations, the recording system can take down what is delivered to it. Phrased another way, it is conceded now that the operation inside the studio is the point where the recording is made or broken. Unfortunately, many television shows are rehearsed so little that certain fundamental rules that affect the quality of a television recording are violated. Whenever this is done the results are extremely unfortunate. To be more specific, it is necessary that lighting be handled with extreme care. A lighting contrast of

no more than 3 or 4 to 1 should be maintained at all times. In addition, since generally more than one camera is used in a television studio the camera angles must be carefully observed so that lighting will be adequate regardless of which camera is in operation. Furthermore, camera levels must be controlled in order to maintain a balance between cuts. It is much more important that this balance be observed when television recording than when producing a show which will be released only as a live show.

Fig. 8. Eastman 16-mm television projector, model 250.

The sound portion of television recordings has been handled in numerous ways by the various studios throughout the country. Some of the best sound has been obtained through the use of tape recording which is synchronized electrically or by the use of perforated tape. Both single and double system recordings are still employed.

A new complete chain of equipment for either television recording or large-screen television projection by an intermediate film system has been developed by General Precision Laboratory, Inc.[52] This equipment consists of a high-quality monitor, 16-mm recording camera, rapid film processor and projector. The monitor is provided with electronic blanking for the frame-rate conversion and gradient correction circuits. The camera has the rapid pull-down required of all television recording cameras and a high-quality sound-recording head. The rapid film processor can be used directly with the camera or separately.[53]

During 1950 the Navy Special Devices Center continued their studies of television as a method of mass training in the Armed Services. The psychological studies to measure the relative effectiveness of television training showed conclusively a definite superiority over direct classroom instruction. In the spring of 1950 the Signal Corps Photographic Center collaborated with the Special Devices Center to present eight weeks of one-hour programs over a ten-city CBS network to reach approximately 5,000 reserves.

In continuing its investigations of new television equipment for Navy use, work was advanced toward the final design of a prefabricated classroom which could be mass produced in time of emergency.

The Navy experiments have attracted wide attention and have helped

focus the interest of educators on television training. The recent FCC hearings on allocations for educational television stations is concrete evidence of this aroused interest.

The first acceptable motion picture photography of color television kinescope images was performed by the Navy, combining techniques developed for recording of radar PPI scopes and television kinescopes. A modified professional 16-mm camera and a specially designed high-speed 25-mm *f*/0.7 lens were employed.

Television Remotes. The tremendous impact of television as a means of taking the home audience to the scene of a remote, whether it be a sporting event or another type of special feature, has been demonstrated time and again during 1950. In fact, the effect of television on the local audience at a sporting event has created a national controversy. The "gate" at football and baseball games has been increased, decreased and unchanged—depending entirely upon whom you talk to and in what part of the country your conversation takes place. However, that the public enjoys the telecasts of such events is without controversy.

Theater Television. In the early months of 1950, RCA completed the design of its first commercial theater television equipment, the Model PT-100 (Fig. 9). This is a direct-projection system employing a projection kinescope and Schmidt optics. A pilot run was placed in production and twelve equipments were delivered and

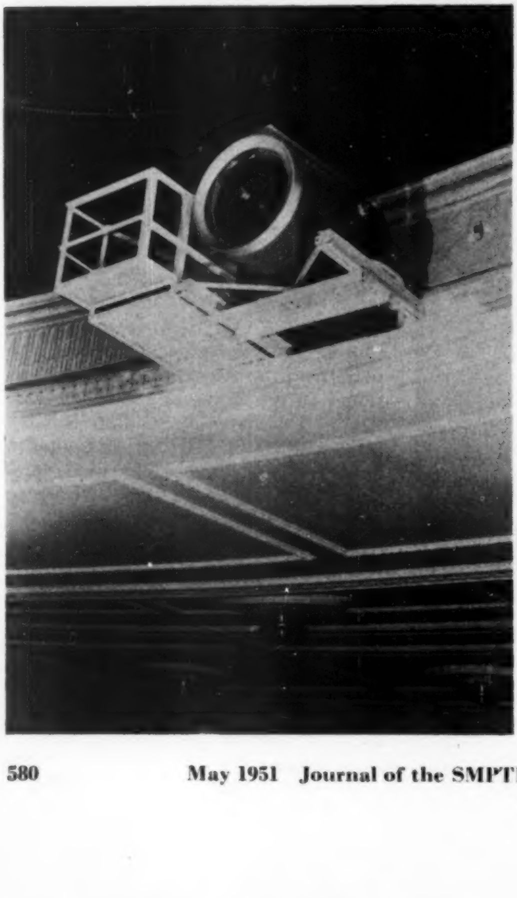


Fig. 9. RCA theater television projector.

installed in theaters in Providence, Albany, Binghamton, Brooklyn, the Bronx, Queens Village, Chicago and Los Angeles in time for the start of the fall football season.

At the Theatre Equipment and Supply Manufacturers Convention in Chicago in October, General Precision Laboratory announced and demonstrated an intermediate film theater-television equipment using 16-mm film. This unit was later demonstrated at the Theatre Owners of America Convention in Houston and at the SMPTE Convention at Lake Placid.[52,53]

United Paramount Theaters, Inc., installed Paramount's intermediate film equipment in one of its Detroit theaters just prior to the start of the football season.

The Eastern theaters have all shown a series of football games carried by the television broadcasting networks. In spite of the fact that the theaters were attempting to sell entertainment that was available free on home television the over-all boxoffice results were highly favorable and improved as the season advanced.

Several of the theaters are using television news programs on a daily basis to replace a regular film newsreel. This has been very popular because of the timeliness of the news.

United Paramount Theaters obtained the exclusive television rights to the University of Illinois and University of Michigan football games and showed them in theaters in Chicago and Detroit. Attendance at these first exclusive showings was very satisfactory with sellouts toward the end of the season.

A group of Eastern theaters is working on exclusive programming which they hope to get under way before the year is out.

Twentieth Century-Fox is moving rapidly toward setting up a large network of theaters in Southern California to be programmed on a closed-circuit basis from a company-owned television studio.

The French Company, Debrie-Radio-Industrie, made a demonstration at the Madeleine Theater, Paris, of a system of cathode-ray tube photography and rapid development on 16-mm film which placed the picture on a full-size theater screen 80 sec after the transmission of the television picture.

It was reported that Twentieth Century-Fox has secured the exclusive use of the Swiss Eidophor system for theater television. This system provides excellent image clarity and screen brightness and uses a high intensity carbon arc as a light source.[54,55]

The Committee

C. W. Handley, *Chairman*

J. E. Aiken	W. F. Kelley
W. L. Bell	R. E. Lewis
P. G. Caldwell	W. A. Mueller
J. W. Duvall	B. F. Perry
T. J. Gibbons	E. H. Reichard
G. H. Gordon	W. L. Tesch
G. R. Groves	

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69th Semiannual Convention

ATTENDANCE at the New York Convention set an all-time record with 659 registrations logged between Monday morning and Friday afternoon, April 30—May 4. It was a full program comprised of 60 technical papers, six engineering committee reports, generous discussion in many of the sessions, and 15 engineering committee meetings held during the week.

On Monday morning registration got off to a slow start but by noon the registration staff (Bill Kunzmann, Erv Geib, George Gordon and Paul Ries) were knee-deep in cash customers. There was a heavy turnout for the Get-Together Luncheon. Peter Mole officially opened the Convention with some pertinent and potent remarks which are published below, immediately followed by the luncheon address by Nathan D. Golden, Director of the Motion Picture Photographic Products Division of the NPA.

Get-Together Luncheon Remarks by President Mole

SEVERAL TIMES since I became President I have been asked whether or not the Society of Motion Picture and Television Engineers can carry water on both shoulders—meaning of course, is it possible for the Society to serve the needs of both motion pictures and television at the same time. My answer is that the Society has been and is now serving these related interests successfully. It intends to continue doing so in the future with increasing effectiveness. In the eyes of the engineer no conflict exists between motion pictures and television because both are mutually related methods of pictorial communication—they both provide pictorial rendition of action that has occurred at another place or at another time. Because the two are very closely related, I believe their techniques and their processes can be applied interchangeably on a broad scale, resulting in joint contributions of great value. The change of the Society's name a year ago to include the word "television" was formal recognition by the engineers of these interrelationships.

Just as television has come to rely heavily on motion picture films and on the techniques of motion picture studio production, so must the motion picture producer and exhibitor seek out, experiment with, and adopt new techniques that appear to have commercial possibilities. This calls for courage and imagination unclouded by the fears which the present economic conditions have produced within the motion picture industry.

Remembering the economic boost that followed the introduction of sound, many people have said recently that great new technical strides must be taken at once to keep the motion picture industry prosperous. In my opinion the present state of affairs is quite the contrary, however, because technical contributions already at hand are far ahead of the industry's willingness to adopt them. The lack of interest in commercializing these developments now may have the effect of applying a brake on future technical growth. If allowed to continue, it could become a demoralizing influence upon our engineers and research workers. I refer not only to the early application of television by the motion picture industry but also to: the potentialities of the increased use of color, multiple sound tracks, wide angle pictures and stereoscopy. Any of these things might recapture the interest of the moviegoing public.

In our Society we have been able to unite engineers from the motion picture field with engineers from radio and from other fields into a unified organization in which one group complements the other. Has the same result been accomplished within the motion picture industry? I am afraid it has not. Do the engineer, producer and exhibitor work hand in hand? The answer is an unequivocal No.

The past success of the motion picture industry was made possible by men who had the intuition to foresee its great

potential future and were willing to risk time and money in exploiting it. It is quite possible that this same pioneering spirit will be needed again before the technological advancements already known are properly applied.

Unfortunately, in many instances the men who head the motion picture industry and who should translate invention into commercial reality have become so economy minded that their first question concerning a new technical process or product is "What will it cost?" and not "How can it benefit this industry?"

We in the Society of Motion Picture and Television Engineers are constantly improving the technical elements of the pictorial rendition of action. It is now up to the producers and exhibitors of motion pictures to take advantage of our technical developments and to continue their business as the most effective medium of mass education and entertainment yet devised.

Address by Nathan D. Golden, Director of the NPA Motion Picture Photographic Products Division

I IMAGINE that a good many of the scientists and engineers here feel that the actions and orders of the National Production Authority are aimed at just about everybody in the industry except yourselves. Of course, the people who are most directly affected by such orders are controllers, purchasing agents and production managers. The NPA Orders generally concern limitations on the procurement of raw materials involving a reduction in the number of products which can be produced.

Now, what I hope to get across to you gentlemen is the fact that, while others in the industry may actually put into effect the changes required by the NPA orders, engineering has an absolutely vital job in curing the problems created by material scarcities, which have largely made necessary the issuance of those NPA orders. That job is as vital to the industry as it is to the defense effort and to the nation's economy.

Before I explain in detail what we believe is the responsibility of this Society and each of its members in the defense mobilization program, I would like to review briefly just what has been going on since the program got under way.

Last September, when Congress passed the Defense Production Act of 1950, employment was practically at an all-time peak. The national personal income was climbing to over two hundred twenty-three billions of dollars for the year. Most consumer products were coming off the assembly lines in volumes unsurpassed in history. Home building was at a new level. Naturally, when the impact of the military demands was imposed on top of this wide-open economy, dislocations of production and distribution of many consumer goods immediately resulted.

From the outset of defense mobilization, the Government was faced with two definite jobs: first, to give the green light to all defense programs and to see that materials and productive capacity were made available to meet the delivery schedules; and second, to halt inflationary trends and, equally important, to keep the domestic economy strong through encouraging maximum civilian production with a minimum of disruption to American manufacturers.

To meet these objectives, the NPA promptly issued regulations establishing the percentage of a base-period production allowed each manufacturer. Other regulations promoted the equitable distribution of available supplies of such basic materials as steel, copper, zinc, tin, aluminum, textiles, rubber and certain chemicals. Subsequently, the constantly increased military demands have made it necessary to curtail more severely the manufacture of hundreds of end-products considered less essential to our economy.

Of course, practically all manufacturers have been affected in some degree by these general cutbacks—some have been severely hit. Wherever possible, hardship cases have been adjusted to protect business, particularly small business, and to minimize unemployment during this transition period. Defense orders and subcon-

tracts now totaling billions of dollars should help to relieve this situation soon. Meanwhile, the diversion of materials, end-products and facilities from normal civilian consumption to defense use cannot be avoided. It is inescapable, and as time goes on further diversion in progressively greater amounts is clearly indicated.

Thus, as a result of world conditions, it has become necessary for everyone, both in Government and industry, to recognize the fact that there are not enough raw materials and productive capacity and manpower to maintain our expanded defense program on top of the same high level of civilian economy.

Conservation of Materials

The problem of obtaining materials is complicated by the fact that many major sources of raw materials are in parts of the world where conflict exists. In some significant cases, those sources are in countries whose national interests are such that they may not wish to, or may not be able to, supply us in the immediate future. For example, the major source for hog bristle is China; for certain grades of chromite, the USSR; for crude natural rubber, Malaya; for tin, Malaya; and for tungsten, China. Cobalt comes from the Belgian Congo, mica from India, nickel from Canada, and shellac and talc from India. You can readily appreciate the fact that under present conditions, some of these sources of supply are either substantially cut off, or could very well be cut off in the near future. For this reason, it has become very important that these limited supplies of raw materials be carefully allocated to support the defense program, to create stockpiles against any reasonably foreseeable emergency, and to maintain as high as possible a level of civilian economy.

All of this points up to one serious problem. For some considerable time in the future, it is going to be necessary for you engineers and scientists to find ways and means of using lesser amounts of critical material and to develop substitute materials in designing the products which your companies produce. We look upon this broad problem as *conservation* and consider it of sufficient importance to warrant adding to my staff within a few weeks a thoroughly qualified engineer, who will devote his full time to this subject. NPA's concept of conservation is divided into five categories: simplification, standardization, substitution, specifications, and salvage and scrap.

It is felt that whenever industry itself initiates conservation programs fitting into these categories industry will be more willing to abide by the necessary regulations. The citizens of the country who are producers, consumers and distributors —and often all three in one person—are the best regulators of their own interests. Voluntary standards arrived at by private industry largely obviate the necessity for Federal regulations.

Standardization Program

Now, as we all know, standardization is a function that costs money and must be paid for. Such costs are simply one expense of doing business. They are as much a routine and necessary business expenditure as legal counsel, advertising or market research. The ultimate benefit of voluntary standards to any one company depends upon the cooperate efforts of all parts of business and industry.

You may be interested in knowing that for a number of years, the Commodity Standards Division of the Department of Commerce has aggressively pursued the matter of simplification and has succeeded in effecting many simplified practice recommendations.

Here are a few examples of what has been done in this line. There were formerly 5,580 varieties of pipes, ducts and fittings for air-conditioning equipment, which by voluntary agreement were reduced to 1,225 (or a reduction of 78%). The number of different types of carbon brush terminals has been reduced from 1,500 to 48 (a reduction of 97%). In the case of 50-watt light bulbs, there were formerly nine different shapes, with or without various amounts of frosting, which were reduced to one (making a reduction of 89%). Two years ago there were 347 models of tank-mounted air compressors with ratings between ¼ to 10 horsepower; today there are only 12 models (a reduction of 96%). These are a few of the many accomplishments by this group,

which show what can be done on a voluntary basis, with close coordination between Government and industry.

The Society's Work

The Society of Motion Picture and Television Engineers is well known for its great accomplishments in the field of standardization. It has often been stated that the Standards Committee of the Society is the focal point of most of its efforts. There is no question that the industry would be in a chaotic condition today if this Society had not taken the initiative and obtained approval for the standards which are now largely recognized by the motion picture industry throughout the entire world.

The Society and each of its members must now accelerate this activity, with the objective of producing products equally as good as, or better than, those formerly made available, but using smaller quantities of critical materials. It is easy to argue that an irreducible minimum use of those materials already has been reached. However, so many new materials have come into being and been put to profitable use within the last few years, that this argument does not entirely hold water.

We find that metals which were curiosities a few years ago are now vital to our military programs. The new tools of warfare created by science, such as jet engines, guided missiles, and the like, are suddenly absorbing great amounts of metals for which we were just beginning to find beneficial industrial uses. I think it is fair to say that through aggressive study you can undoubtedly find ways and means of using many available materials in place of critical ones in ways that have not heretofore been considered.

Those programs which the Government has already started are being stimulated by the National Production Authority Conservation Coordinator, to re-examine all types of Federal specifications, with the goal of modifying them wherever possible to reduce the requirements for critical materials. Suggestions from industry in this program will, we are certain, prove to be invaluable.

With respect to salvage and waste, every manufacturer must make every possible effort to minimize this problem. We all know that time and again science and engineering have found ways to use what is considered waste material in one industry as the raw material for another. An intensification of this kind of activity is essential under present conditions.

As you know, for many years the Government has initiated programs for conservation of certain of our natural resources such as our forests. By instituting conservation programs and by planting new trees, it is possible to perpetuate the supply of lumber. Obviously, the same kind of program cannot be utilized in connection with our mineral resources.

Our mineral resources are not going to last forever. Normal civilian production continues to increase year after year. War and defense programs superimposed on our civilian economy every ten or twenty years add another serious drain.

We feel that conservation is a serious responsibility of societies such as yours. We feel that engineers and scientists in every manufacturing concern within the motion picture photographic industry ought to hit hard at this problem through studies and programs which will lead to the conservation of the important critical materials. This represents not only a service which the industry can perform for the national well-being; it is also an intelligent means of promoting the industry's well-being in a time of possible prolonged shortages.

And speaking of shortages, I can think of no better forum than yours to state that as of this moment there is no shortage of motion picture film. I will agree there has been an acute tightness in the supply and that it is difficult to secure delivery on the amount of film desired to build an excess inventory, but as to extreme shortage, there is none, regardless of statements to the contrary by undisclosed sources, who are not in possession of the true facts. Film suppliers and manufacturers inform me, and they should know, that they are still delivering comparable footage to their accounts paralleling 1950 purchases. Under such conditions one can ask no more. While it is true that it limits expansion for securing new business, business comparable to 1950 is better

than what might eventuate under a limitation order, or an allocation system.

The National Production Authority, as well as other Government agencies charged with the responsibilities of carrying out the defense program, earnestly requests your close cooperation so that as a team we can accomplish this objective, not only for the benefit of the country as a whole, but also in order that the motion picture photographic industry can protect its important position in our entire economy.

Papers Program

The extra effort put into advance planning of the Program has already paid tangible dividends. Bill Rivers, local Papers Vice-Chairman, Ed Seeley, Chairman, and a number of members of the Papers Committee started work on the spring program during the previous Convention, at Lake Placid. As a result, it took shape early enough for pre-convention publicity to be comfortably specific for a change. The Tentative Program was mailed to all members at an early date, and attendance was high.

Believing that the discussion of particular papers immediately after presentation should become a part of the printed version, but at the same time being dissatisfied with some previous efforts at recording the questions and answers, the Papers Committee and Board of Governors agreed on the purchase of a small "dictating machine" type of disc recorder. It was used in conjunction with the public address system during all sessions in the Georgian Room. Stenotypists were employed for the three other sessions.

The afternoon sessions included papers on film and processing with E. A. Bertram and F. J. Grignon as Chairman and Vice-Chairman. In the evening, there were papers on motion picture techniques with F. E. Cahill and E. M. Stifle, officiating. Members whose interests lay more in the direction of television were the guests of G. L. Beers at the Voice of Firestone television show staged in the Center Theater Studios of the National Broadcasting Company.

On Tuesday morning F. G. Albin and F. N. Gillette were in charge of the session on television recording and reproduction. At 1:00 P.M. 104 members and guests left by bus for the combined television session and tour of the Bell Telephone Laboratories at Murray Hill, N. J. A. G. Jensen, long active in theater television work of the Society was host to the visitors, on the tour which he and his staff had previously arranged. Dr. R. Bown, Director of Research, extended his greetings to the Society. Chairman of the session was G. L. Beers, and H. C. Millholland was Vice-Chairman. Following the last paper, the group left for dinner at a restaurant near by, returning to the Hotel Statler at about 10:00 P.M.

Wednesday was the busiest day of the week, with four technical sessions and the midweek Cocktail Party and Banquet and Dance. More than 250 members and nonmembers attended the morning and afternoon sessions on high-speed photography held in the Ballroom. Chairmen were M. L. Sandell and C. D. Miller; Vice-Chairmen were Earl Quinn and Kenneth Shaftan. Film projection and screen viewing factors were the subjects of the other two sessions held in the Georgian Room. Chairmen were W. W. Lozier and F. J. Kolb; Vice-Chairmen were A. J. Hatch and C. R. Underhill. To introduce the eating portion of the Wednesday evening festivities, President Peter Mole reminded the assembled party goers of the single-plank platform on which he was elected: "No speeches at banquets." The one paragraph remark was greeted with thunderous applause and followed by several hours of fun and frolic. The festivities broke up about 1:00 A.M.

There was a third group of high-speed photography papers on the Thursday morning session, which was, as usual, well attended in spite of much late revelry the preceding evening. Chairman and Vice-Chairman were Roy Wolford and Richard Painter. In the afternoon Pierre Mertz and Bill Deacy were Chairman and Vice-Chairman of a session including papers on a variety of problems and possibilities related to television.

Two sessions on Friday covered both magnetic and photographic sound recording. J. G. Frayne and R. G. Mann were Chairmen. W. F. Jordan was Vice-Chairman of the morning session.

Highlights, both real and contrived, of the five-day convention were recorded on 35-mm film with 35-mm magnetic sound by a production team under direction of Emerson Yorke. J. Burgi Contner was cameraman and Harry Braun was in charge of the RCA sound crew. Some members who attend the October convention in Hollywood will doubtless see themselves in an unfamiliar role.

Publicity

Leonard Bidwell, with the enthusiastic support of Helen Babigian of the Society headquarters staff, maintained Press Headquarters on the Mezzanine of the Statler. Excellent coverage by the daily trade papers and by the New York daily newspapers was responsible for a large share of the increase in the registrations.

"Session will open with a motion picture short"

Thus read the beginning of each session's description in the 69th Semiannual Convention program. Emerson Yorke, Chairman of the Convention Committee on Motion Pictures, screened 40 films to choose a dozen fine 16- and 35-mm one-reelers. Those attending the Convention were enthusiastic about not only the high quality and cogent subject matter, but also the pertinence of the films as Emerson Yorke arranged them for each session. The films were:

*The Screen Director**	35-mm b & w	Warner Bros.
*The Cinematographer**	35-mm b & w	Paramount
A General Returns	16-mm b & w	NBC-TV News Special Events
*Movies Are Adventure**	35-mm b & w	Universal-International
*History Brought to Life**	35-mm b & w	Paramount
High-Speed Photographic Studies of Welding Arcs	16-mm color	U.S. Navy Bureau of Ships
Glory of Spring	16-mm color	Ott Pictures
Grandad of Races (Academy "Oscar" Award)	35-mm color	Warner Bros.
The Navy in Science	35-mm b & w	U.S. Navy
*The Art Director**	35-mm b & w	20th Century-Fox
*Moments in Music**	35-mm b & w	MGM
*The Soundman**	35-mm b & w	Columbia

Titles marked with an asterisk are from a group of one-reelers, *The Movies and You!* (in several cases they are prereleases), which has been put together by the motion picture industry in cooperation with the Academy of Motion Picture Arts and Sciences, and is designed to present the story of the behind-the-scenes activities in the production of motion pictures. All of these films are available to 16-mm users from Teaching Film Custodians, Inc., Agent for Board of Trustees of *The Movies and You!*, Industry Short Subject Project, 25 W. 43d St., New York 18.

Courtesy Theater Admissions

Entertainment, in addition to the Cocktail Hour and the 69th Semiannual Banquet and Dance and the extensive Ladies' Program, was pleasantly enhanced by courtesy admissions extended by:

Capitol Theatre
Paramount Theatre
Radio City Music Hall
Roxy Theatre
Warner Strand Theatre

Board of Governors

One day before the Convention, Sunday, April 29, the Board of Governors met in New York to review administrative, technical, and publication operations of the Society for the first quarter of 1951.

Agreement was unanimous on the need for additional space for Society Headquarters and the Board endorsed the recommendation that 2000 square feet of available space at 40 West 40th Street be taken without delay. The move, which will take place in the first or second week of June, became necessary because after nearly a year of ineffective negotiating, there appeared to be little chance of securing adequate space in the building at 342 Madison.

It was also agreed that every possible effort should be made to induce many more engineers in both motion pictures and television to apply for membership in the Society. The present trend is in the right direction, but extra attention to this program on the part of all Society members is clearly called for.

Test films, and the need for constant vigilance to maintain their technical quality within the limits of published specifications, were discussed. The Board learned that the search for a qualified test film quality control engineer, previously authorized, had been successful and that Fred Whitney, long associated with the ERPI Division of the Western Electric Co. and Altec Service Corp., had joined the Headquarters staff to serve in that capacity.

Engineering Activities

Fifteen committee meetings were held during the week of the Convention. These were:

Theater Television
Laboratory Practice
Screen Brightness
High-Speed Photography
Television Film Equipment
16- and 8-Mm Motion Pictures
Films for Television
ASA Committee PH22
Film-Projection Practice
Magnetic Recording
High-Speed Photography Liaison of Societies
Optics
Test Film Quality
Film Dimensions
Theater Engineering

Times for the committee meetings were chosen to give a minimum of interference with the Papers Program. Since the program had been assembled several weeks before the Convention and technical papers had then been scheduled for presentation in related subject groups it was not difficult for Hank Kogel and the committee chairmen to steer clear of obvious conflicts. Several committees met prior to the session of most interest to their members so each chairman could give Society members a last-minute report on the current work of his group. In addition, chairmen of certain engineering committees were chosen by the Papers Committee as chairmen of related technical sessions. This was quite appropriate for several reasons: first, the chairman was familiar with the subject matter of papers on his session; second, he could introduce the session with any "oral version" of his Committee's latest report to establish the Society's official interest in the general subject of that session; and third, his knowledge of the subject let him stimulate discussion from the floor following each paper.

BOOK REVIEWS

Father of Radio:
The Autobiography of Lee de Forest
Published (1951) by Wilcox & Follett, 1255 South Wabash Ave., Chicago 5. 502 pp. Appendix and Index. Illus. Price $5.00.

Dipping his pen in a concentrated mixture of emotion and pride, Lee de Forest takes the reader across his years from childhood to today—rarely inhibited and often with a chip on his shoulder, resenting fate and contemporaries. There is no bashfulness in his title "Father of Radio," or in his array of numbered claims of "firsts," including: "1. World's first wireless transmission overland—1904. . . . 4. World's first broadcast—1907. . . . 5. World's first transmission of voices without wires. . . . 8. World's first successful telephone amplifier—1912. . . . 14. World's first theatrical presentation of sound-on-film talking motion picture—1923." The jacket proclamation tends to assert that the world would not have been the same without him and points to the "electron tube," meaning the Audion, declaring the debt of radio, phonograph, talking pictures, television, radar, the cyclotron, the guided missile," etc. "Even atomic bombs would be impossible without it."

Dr. de Forest's account of himself is extraordinarily subjective, even for an inventor's book about himself. The volume is curiously interlarded with the sweet dolor of his loves and marriages, and here and there bursts into poesy. You are liable to fall out of the laboratory into the moonlight as you turn a page and there is in addition an appendix, pages 469 to 476, entirely devoted to his odes and vesper songs.

Another appendix section presents extracts from his paper read before The Franklin Institute in 1920 to relate the evolution of the Audion, which is appropriate enough as bearing on Dr. de Forest's best known contribution. This reviewer thinks it could have been fuller.

Dr. de Forest traces the Audion's ancestry back to his quest for a detector for wireless signals. He explored their possible effects on heated gas from such sources as the incandescent mantle lamp and the Bunsen burner, to no avail. Then he came upon a notion about the incandescent filament electric lamp. In the paper, he lightly and swiftly passes over a possibly highly basic fact with: "I was familiar with the Edison effect and many of the investigations thereof carried on by scientists."

That "Edison effect" can do with a bit more attention. In the early years of the incandescent light, Edison sought to double the life of the fragile lamp by making it with a spare filament, which could be cut into circuit when the first burned out. He found that there was an unexpected electrical potential generated in the idle spare filament when the first was in service. In fact he set William Kennedy Laurie Dickson, he of mixed and unhappy later fame in motion picture matters, to work exploring the subject and filling a notebook with data. There was too much to explore and do in those fecund and often troubled days and the "Edison effect" went into the future file, where it was to repose.

That for the reference to the "Edison effect," in the appendix. Now turning forward into the narrative, page 213, says Dr. de Forest: "Repeated failure with our own crude instruments and skill finally induced me in 1905 to follow Babs' advice to lay the problem of constructing an incandescent lamp containing a carbon filament and a small platinum plate . . . in the lap of a manufacturer of miniature lamps . . ."

Now to identify this helpful "Babs" one turns farther forward to page 151 of the narrative and finds: "At this stage (1902–03) I hired a queer looking, hawk-nosed inventive individual endowed with an encyclopedic memory by the name of Clifford D. Babcock. He had a wide experience with various inventors, Edison among others . . ."

This adds up, not to any animadversion on the origin of the Audion, but to observe that organization of the facts could have been improved. Sometimes Dr. de Forest is more poet than scientist. —Terry Ramsaye, New Canaan, Conn.

American Standard Abbreviations for Use on Drawings, Z32.13-1950

Published (1950) by the American Standards Association, 70 E. 45th St., New York 17. 32 pp. 8½ × 11 in. Paper bound. Price $1.00.

This newly revised edition has profited from the several years field experience of its predecessor which was published in 1946. As stated in the foreword to the 1950 edition, "primary consideration was first given to suggested changes and additions volunteered by users of the standard." The new standard contains well over 2000 abbreviations selected for use on drawings where space and drafting time are considerations. These abbreviations are not intended for use in text matter or equations.

The abbreviations listed are, on the whole, for specialized terms that would in many cases be known and understood only by specialists in each of the various technical fields covered. This standard, therefore, would be of considerable help to anyone required to read or prepare drawings in a field other than his specialty. Motion picture and television engineers, for example, would have little difficulty in recognizing abbreviations such as MC, TV or UHF. If they strayed into other technical fields, however, they would certainly require the assistance of the Standard for such as APCI or NP.

Abbreviations in the electronics and television fields are extensive, but those relating to the motion picture field are scant. PROJ, for example, stands for project or projectile but not projector or projection. No abbreviations are given for camera, motion picture or angstrom. Also in the realm of constructive criticism, the section of the standard entitled "A Partial List of Engineering Societies and Industrial Associations" would benefit by including the Society of Motion Picture and Television Engineers (SMPTE) and by showing the revised name of the Radio and Television Manufacturers Association (RTMA). The standard, however, is an ever-growing compilation and this edition should be recognized for the excellent coverage it has given to so many varied and complex fields.—Charles A. Meyer, Tube Department, Radio Corporation of America, Harrison, N.J.

The Use of Mobile Cinema and Radio Vans in Fundamental Education

Published (1949) by the United Nations Educational, Scientific and Cultural Organization (UNESCO), Publication No. 582. Distribution agent in the U.S.A., Columbia University Press, 2960 Broadway, New York 27. 164 pp. 26 pp. photos and diagrams. 5¼ × 8½ in. Paper cover. Price $1.00.

Mobile projection trucks (or vans) have been used only to a slight extent in the United States, for there is hardly a town or community in the settled portions of this country that does not either own its own sound-on-film and slide projector or have access to one. There are, however, some districts—for instance in the Appalachian highlands, the far South and the desert areas of the western states—where complete projection facilities, including power supply and living quarters, might fill a need. This book is of special interest for those who may want to bring educational films to people to whom more permanent facilities are not available.

The Use of Mobile Cinema and Radio Vans in Fundamental Education was prepared for UNESCO by the Film Center in London. It describes traveling radio and motion picture exhibition units and outlines the history and use of such units in Great Britain and the colonies, Canada, Russia and other countries. In these places the mobile units are under the education, public health or information departments of the governments.

Complete data are given for the building and furnishing of a truck with 16-mm motion picture, slide film, radio receiving and public address equipment. Included are details of such features as shock mounting, tropical treatment, stowage and living quarters for the crew.

One interesting application was the rebuilding of an army "duck," complete with power and living quarters, in order to show educational motion pictures to residents on the rivers in India.

There is a wealth of information in the appendixes. References, bibliography, equipment specifications, training courses, diagrams and excellent photographs complete the book.—William K. Aughenbaugh, Radio Station WLW-T, The Crosley Broadcasting Corp., Cincinnati.

Proceedings of the Speech Communication Conference at M.I.T.

These *Proceedings* were published as a unit of 116 pp. which is part of the *Journal of the Acoustical Society of America*, vol. 22, no. 6, Nov. 1950. The following twenty-four papers were presented at this conference held May 31–June 3, 1950, at Massachusetts Institute of Technology, under the joint auspices of the Acoustical Society of America, the Carnegie Project on Scientific Aids to Learning at M.I.T., and the Psycho-Acoustic Laboratory at Harvard University:

Introduction: A Definition of Communication, S. S. Stevens, Psycho-Acoustic Laboratory, Harvard University, Cambridge, Mass.

The Information Theory Point of View in Speech Communication, R. M. Fano, Research Laboratory of Electronics, M.I.T., Cambridge, Mass.

Speech, Language, and Learning, Norbert Wiener, M.I.T., Cambridge, Mass.

Typology of Languages, Paul Menzerath, Phonetic Institute, Bonn University, Germany

Description of Language Design, Martin Joos, University of Wisconsin, Madison, Wisconsin

The Relation of Phonetics and Linguistics to Communication Theory, Oliver H. Straus, Research Laboratory of Electronics, M.I.T., Cambridge, Mass.

Speech and Language, John Lotz, Columbia University, New York, N.Y.

Pathology in Speech Communication, Ira J. Hirsh, Psycho-Acoustic Laboratory, Harvard University, Cambridge, Mass.

Language Engineering, George A. Miller, Psycho-Acoustic Laboratory, Harvard University, Cambridge, Mass.

Communication Patterns in Task-Oriented Groups, Alex Bavelas, Research Laboratory of Electronics, M.I.T., Cambridge, Mass.

Sonograph and Sound Mechanics, Jean Dreyfus-Graf, Geneva, Switzerland

The Calculation of Vowel Resonances, and an Electrical Vocal Tract, H. K. Dunn, Bell Telephone Laboratories, Inc., Murray Hill, N.J.

An Apparatus for Speech Compression and Expansion and for Replaying Visible Speech Records, F. Vilbig, Air Force Cambridge Research Laboratories, Cambridge, Mass.

Spectrum Analysis, Franklin S. Cooper, Haskins Laboratories, New York, N.Y.

Correlation Function Analysis, L. G. Kraft, Research Laboratory of Electronics, M.I.T., Cambridge, Mass.

System-Function Analysis of Speech Sounds, W. H. Huggins, Air Force Cambridge Research Laboratories, Cambridge, Mass.

Portrayal of Some Elementary Statistics of Speech Sounds, S. H. Chang, Electronic Research Project, Northeastern University, Boston, Mass.

Autocorrelation Analysis of Speech Sounds, K. N. Stevens, M.I.T., Cambridge, Mass.

Theory of Operation of the Cochlea: A Contribution to the Hydrodynamics of the Cochlea, O. F. Ranke, Physiologisches Institut, University of Erlangen, Germany, U.S. Zone

Theory of the Acoustical Action of the Cochlea, J. Zwislocki, University Clinic for Ear, Nose and Throat, Basel, Switzerland

Neurophysiology of the Auditory System, Robert Galambos, Psycho-Acoustic Laboratory, Harvard University, Cambridge, Mass.

Auditory Masking and Fatigue, Walter A. Rosenblith, Psycho-Acoustic Laboratory, Harvard University, Cambridge, Mass.

Binaural Localization and Masking, W. E. Kock, Bell Telephone Laboratories, Inc., Murray Hill, N.J.

Reversed Speech and Repetition Systems as Means of Phonetic Research, W. Meyer-Eppler, Phonetisches Institut der Universität, Bonn, Germany

Single copies of this *Journal* are available at $2.00 each from the American Institute of Physics, 57 E. 55th St., New York 22.

Dictionary of Color
New Second Edition

By A. Maerz and M. R. Paul. Published (1950) by McGraw-Hill, 330 W. 42d St., New York 18. 208 pp. 8¾ × 11¾ in. Price, $25.00.

From inspection of the sample sheet sent out with literature advertising the second edition of this standard color names dictionary, it would seem that the job of reproducing the first edition has been a good one. Over seven thousand samples appear in the book, with color names keyed to samples matching (for the first edition) a wide series of color names taken from several sources to represent standard usage in many fields. In the second edition many names have been added, including those for the 9th edition of the *Standard Color Card* of the Textile Color Card Association of the United States, and those sponsored by *House and Garden*. Because newly developed pigments were used in this edition with a resulting "improvement of depth, purity, and brilliance of many of the colors, with small shifting of match in some cases" it is advised by the publishers that the edition of the book be stated when exact match or reference is desired. Eight groups of hue ranges are shown in plates of 144 or 72 blocks to a page, each group consisting of several pages which extend from the purest colors, through successive pages for darker, grayer colors until they reach near-blacks. The Maerz & Paul dictionary provides a large assortment of color samples at a very reasonable price. It has proved a standard reference work for color names since its original publication in 1930. The second edition should continue to fill the need for this type of color reference work.—Dorothy Nickerson, Cotton Branch, PMA, United States Department of Agriculture, Washington 25, D.C.

Descriptive Color Names Dictionary

Edited by Helen D. Taylor, Lucille Knoche and Walter C. Granville. Published (1950) by Container Corporation of America, 122 E. 42d St., New York 17. 60 pp. Price $2.00.

This 60-page dictionary of color names used in mass-market merchandising, such as in the mail-order field, describes current work in the color names field. Both Mrs. Taylor and Miss Knoche have been collecting information and keying color names to materials actually used by large mail-order houses such as Sears Roebuck and Montgomery Ward, for many years. In this dictionary they have keyed the names to samples in the third edition of the *Color Harmony Manual*, published last year by the Container Corporation. While the book is intended as a supplement to the *Color Harmony Manual*, nevertheless it should be useful for general color names work, particularly when ICI and Munsell specifications are published for the samples of the *Manual*. Because the work has been done by persons so close to mass-market merchandising use, it should carry considerable authority. Publication of colorimetric data on the samples to which the names are keyed is promised by Mr. Granville for the near future. While some of the names overlap, so that several names may apply to the same sample, for other samples in the *Manual* no mass-market names are in use. The publication should be very useful to all interested in color names; it is a must for those who own the *Manual*.—Dorothy Nickerson, Cotton Branch, PMA, United States Department of Agriculture, Washington 25, D.C.

Journals Out of Stock: The Society's stock of Journal issues for March, Part II, July, August, September, 1949, and February, 1950, has been exhausted as a result of an unexpected increase in demand and the Society's Headquarters is anxious to purchase a stock of each. Members or libraries having extra copies available are invited to send them in. The going price is 75c.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April Journal.

New Members

The following members have been added to the Society's rolls since those published last month. The designations of grades are the same as those used in the 1950 MEMBERSHIP DIRECTORY.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Anderson, Vernon E., Photographer and Laboratory Technician, Society for Visual Education, Inc. **Mail:** 2955 N. Nordica Ave., Chicago 34, Ill. **(A)**

Armstrong, A. Millard, Attorney, 529 Fairwood Ave., Columbus 5, Ohio. **(A)**

Aulabaugh, Sarah Jane, Research Photographer, Monsanto Chemical Co. **Mail:** 436 Red Haw Rd., Dayton 5, Ohio. **(M)**

Behrend, William L., Research Engineer, RCA Laboratories. **Mail:** 357 Nassau St., Princeton, N.J. **(M)**

Bunting, Eugene N., Bay State Film Productions, Inc. **Mail:** 65 Lee St., East Longmeadow, Mass. **(M)**

Burleson, John E., Information and Education Specialist, Navy Department. **Mail:** 3356 Martha Custis Dr., Alexandria, Va. **(A)**

Burrell, John E., Television Engineering Supervisor, National Broadcasting Co. **Mail:** 11602 Hartsook St., North Hollywood, Calif. **(A)**

Castle, Clemens X., Chief Engineer, WJIM-TV. **Mail:** 315 W. Brown St., Birmingham, Mich. **(M)**

Chaney, Harold Lee, University of Southern California. **Mail:** 660 W. Jefferson Blvd., Los Angeles 7, Calif. **(S)**

Cherry, Herbert, Stage Electrician, Park Theatre. **Mail:** 1916 N. Stanley St., Philadelphia 21, Pa. **(A)**

Chesley, Albert Bernard, Washington University. **Mail:** 216 S. Fifth St., Fort Dodge, Iowa. **(S)**

Cunliffe, Donald C., Sound Recorder, Universal-International Pictures Co. **Mail:** 4356 Lemp Ave., North Hollywood, Calif. **(A)**

Eckhard, Henry W., Television Projectionist, KPIX. **Mail:** 71 Liebig St., San Francisco Calif. **(A)**

Fagerstrom, William H., Motion Picture Operator, F.W.C. Theaters. **Mail:** 719 Westbourne Dr., Los Angeles 46, Calif. **(A)**

Franco, Maurice, Electronic Project Engineer, Houston Corp. **Mail:** 527 N. Mott St., Los Angeles 33, Calif. **(A)**

Gisbrecht, James H., Electrical Engineer, Northrop Aircraft. **Mail:** 10323 Mansel Ave., Inglewood, Calif. **(A)**

Goris, Edward N., Sales Engineer, General Electric Co. **Mail:** 212 N. Vignes St., Los Angeles, Calif. **(A)**

Gray, John B., Senior Electrical Engineer, Diebold, Inc. **Mail:** 13 Senga Rd., South Norwalk, Conn. **(M)**

Harmon, Ralph N., Engineering Manager, Westinghouse Radio Stations, Inc. **Mail:** 1625 K St., N.W., Washington, D.C. **(M)**

Hayes, Roy O., Chief Projectionist, Columbia Amusement Co. **Mail:** 713 Kentucky Ave., P.O. Box 123, Paducah, Ky. **(A)**

Hillie, Edward M., Television Director, KNBH, National Broadcasting Co., Inc., Sunset and Vine, Hollywood 28, Calif. **(A)**

Hobby, Fred, Film Technician, Guffanti Film Laboratories, Inc. **Mail:** 2007 Newbold Ave., New York 61, N.Y. **(A)**

Hoffman, Donald D., Motion Picture Cameraman, The Calvin Co. **Mail:** 3130 Euclid, Kansas City, Mo. **(A)**

Holland, Sheldon C., Manager, Photographic Dept., Bell Aircraft Corp. **Mail:** 78 Briggs Ave., Buffalo 7, N.Y. **(A)**

Hotchkiss, Calvin M., Photographic Engineer, Motion Picture Division, Eastman Kodak Co., 342 Madison Ave., Suite 626, New York 17, N.Y. **(M)**

Hunt, Thomas E., Partner, Colortran Converter Co. **Mail:** 7045 Romaine, Hollywood 38, Calif. **(M)**

Jewell, Raymond W., University of Southern California. **Mail:** 837 W. 36 Pl., Los Angeles 7, Calif. **(S)**

Knight-Simpson, Beric W., Cinema Officer, Nigerian Government. **Mail:** Public Relations Dept., 11 Custom St., Lagos, Nigeria, West Africa. **(A)**

Kugel, Gerhard W., Audio Recording Technician, Dallas Jones Productions. **Mail:** 1725 N. Wells St., Chicago, Ill. **(A)**

Latil, J. P., President, Genarco, Inc. **Mail:** 116-46—82 Dr., Kew Gardens, N.Y. **(M)**

Ledoux, Robert F., Chief, Photographic Laboratory, Springfield Armory. **Mail:** 102 Draper St., Springfield, Mass. **(A)**

Levene, Sanford M., New York University. **Mail:** 62-65 Saunders St., Rego Park, N.Y. **(S)**

Lewis, Joseph R., Vitapix Engineer, American Broadcasting Co. **Mail:** 629 Casanova St., Bronx 59, N.Y. **(A)**

Luckey, Richard S., University of Southern California. **Mail:** 942 W. 34 St., Los Angeles 7, Calif. **(S)**

Moltz, Jerome Winslow, II, University of Southern California. **Mail:** 6452 W. 85 Pl., Los Angeles 45, Calif. **(S)**

Moran, Austin G., Chief Engineer, Dominion Broadcasting Co. **Mail:** 6 Baby Point Ter., Toronto, Canada. **(A)**

Moyer, Eldon, Motion Picture Work, Eastman Kodak Co. **Mail:** 31 Holcroft Rd., Rochester, N.Y. **(M)**

Muchmore, John, Sound Maintenance Engineer, Universal Pictures Co. **Mail:** 10724 Aqua Vista St., North Hollywood, Calif. **(A)**

Nicholas, Guy E., Photographer, State Highway Commission, State of Maine. **Mail:** 101 N. Main St., Rockland, Me. **(A)**

Orrell, Percy, Agent, Ampro Corp. **Mail:** 34 Mendon St., Hopedale, Mass. **(A)**

Plumb, Edward W., Film Director, The Standard Oil Co. (Ohio). **Mail:** 3167 W. 92 St., Cleveland 2, Ohio **(A)**

Preo, Paul H., Development Engineer, Eastman Kodak Co. **Mail:** 331 Conrad Dr., Rochester 16, N.Y. **(A)**

Pugliese, Guy, Photographer, Commonwealth of Pennsylvania. **Mail:** 2635 Jefferson St., Harrisburg, Pa. **(A)**

Rengel, Richard E., University of Southern California. **Mail:** 7953 Ranchito Ave., Van Nuys, Calif. **(S)**

Reynolds, Floyd L., Test Engineer, Universal-International Pictures Co. **Mail:** 4514 Farmdale, North Hollywood, Calif. **(A)**

Ries, Irving G., Special Photographic Effects, Metro-Goldwyn-Mayer. **Mail:** 17501 Castellammare Dr., Pacific Palisades, Calif. **(M)**

Ruskin, Phil, TV Remote Director, WBKB. **Mail:** 5717 N. Christiana, Chicago 45, Ill. **(A)**

Rzewinski, Leonard, Engineer, Meridian Instrument Corp. **Mail:** 261 Montauk Ave., Brooklyn 8, N.Y. **(A)**

Seat, E. Toral, Director of Bureau of Visual Education, World-Wide Bible Pictures, Pacific Union Conference. **Mail:** 709 Glenmore Blvd., Glendale 6, Calif. **(M)**

Shekell, Lennox, University of Southern California. **Mail:** 1039 W. 31 St., Los Angeles 7, Calif. **(S)**

Simmons, James W., Photographer, 4124 Park, Kansas City, Mo. **(A)**

Stevens, M. H., Manager, Industrial Sales Division, Bausch & Lomb Optical Co. **Mail:** 20 Alexander St., Rochester 20, N.Y. **(M)**

Valentine, Fred, Heald Engineering College. **Mail:** P. O. Box 4687, San Francisco, Calif. **(S)**

Vaughan, William Kent, Engineer, Carthage Machine Co. **Mail:** 226 N. School St., Carthage, N.Y. **(A)**

Weiser, Sidney, Mechanical Engineer, Federal Manufacturing and Engineering Corp. **Mail:** 255–43 75 Ave., Floral Park, L.I., N.Y. **(M)**

White, George C., Jr., Physicist, Frankford Arsenal. **Mail:** 3515 N. 22 St., Philadelphia 40, Pa. **(M)**

Wilson, Carlton F., Producer-Director, Imperial Oil, Ltd. **Mail:** 365 Bayview Ave., Apt. #6, Toronto, Ontario, Canada. **(M)**

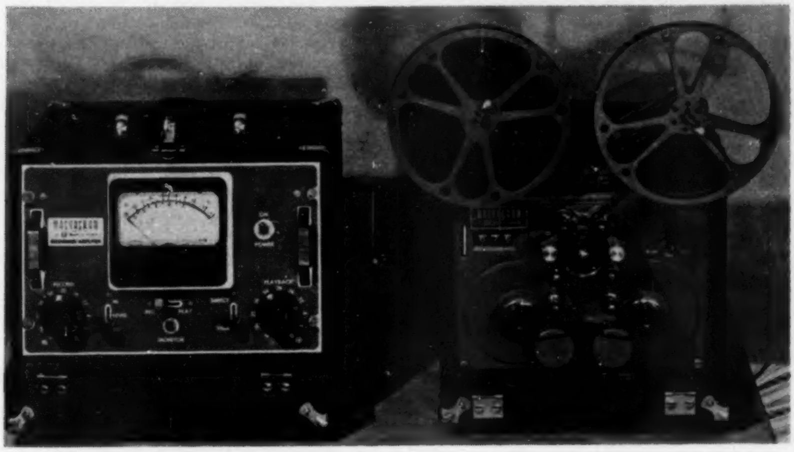
Personals

Dr. Adolph H. Rosenthal, formerly Director of Physics for the Freed Radio Corp., New York, has been appointed Vice-President and Director of Research and Development. Prior to his association with Freed Radio, Dr. Rosenthal was engaged for many years in electronic research for American and British concerns. Best known among his 30-odd patents is the Skiatron or "dark-trace" cathode-ray tube which has had a wide application in television, motion pictures and military electronics. At one time, Dr. Rosenthal was engaged in research at the Einstein Institute in Potsdam, applying television methods to solar observations. He will supervise government development projects for which Freed has built enlarged laboratory facilities.

Louis Gerard Pacent, a Fellow of the SMPTE, has been awarded the Marconi Memorial Medal of Achievement for his pioneer work in radio and communication by the Veteran Wireless Operators Association. At the beginning of Mr. Pacent's career, he worked very closely with Marconi himself. Mr. Pacent was a pioneer in the manufacture of theater motion picture sound reproducing equipment, and his many installations in 1929 and 1930 gave impetus to the infant talking picture and made it possible for exhibitors to take advantage of the new art. He is now president of the Pacent Engineering Corp., New York. His many contributions to the war effort during World War II brought citations to his company.

New Products

Further information about these items can be obtained directly from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.

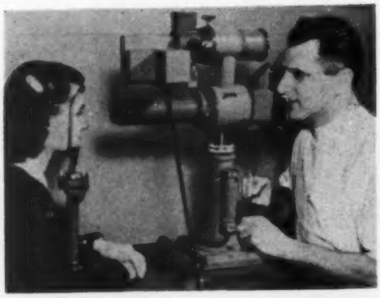


A magnetic film recorder that weighs only 38 lb distributed over two cases, the mechanical-drive case being 11 × 9 × 8 in. and the amplifier case being 12 × 8½ × 8 in., is being marketed by the Magnagram Corp., 11338 Burbank Blvd., P.O. Box 707, North Hollywood, Calif. Known as F-102 Field Unit Sub Miniature Magnetic Film Recorder, it incorporates the Magnagram "Synkinetic" dual-inertia wheel drive with flutter under 3%.

Frequency response is 50 to 10,000 cps within 2 db at 90 ft per min. Film capacity is from 400 to 1200 ft (up to 33 min of recording). Amplifier terminals provide for low-impedence mike and 600-ohm zero-level inputs and 600-ohm zero-level output. There is a 4-in. illuminated V.U. meter, direct, and "off-the-film" monitor. A large, easy-to-read footage counter is interlocked with drive shaft to operate forward and in reverse. The recorder is designed to operate vertically or horizontally. The universal motor drive is readily adaptable to operation with selsyn and other interlock motors. 16-Mm or 17½-mm film drive is optional.

A high-quality instrument for the synchronization and measurement of 16-mm and 35-mm films, known as the Syncrometer, is being produced by National Cine Equipment, Inc., 20 W. 22d St., New York 10. The Syncrometer provides finger-tip roller release and positive roller contact, and prevents film sprocket jump at any rewind speed.

Any combination of 16-mm and 35-mm sprocket assemblies can be made by the manufacturer. The Syncrometer is of the foot-linear type, graduated for 40 frame divisions on the 16-mm sprocket and 16 frame divisions on the 35-mm sprocket. Film stripper shoes prevent film creep under sprockets.



A high-speed still camera for photographing the retina, nerve fibers and other structural elements of microscopic size in the interior of the eye is now being produced by Bausch & Lomb Optical Co., 635 St. Paul St., Rochester 2, N.Y.

Bausch & Lomb developed the camera at the request of the U.S. Public Health Service for studies showing the relationship between enlarged retinal blood vessels and such vascular diseases as high blood pressure and arteriosclerosis. It is being used extensively in the "rice diet" research and treatment of these diseases. Photographs of the interior of the eye are taken periodically and superimposed so that the diameter and tortuosity of blood vessels may be compared at various stages of treatment.

Eye pathologies such as abnormal condition of blood vessels, location and extent of hemorrhages, pigmentation, and extent of cupping of the nerve head may be studied with the new camera. The last condition is of importance in diagnosing and treating glaucoma, and the photographs may aid in detecting, in addition to those mentioned, such systemic diseases as diabetes, nephritis, and tumors of the central nervous system where changes in the retina occur long before the appearance of clinical symptoms.

Series photographs of these conditions may be used to chart their progress and as a visual aid for teaching medical and optometric students. Photographs may be enlarged many times or projected onto a screen for scrutiny by surgeons before and after operations. Photographs of the anterior segment of the eye—the lids, iris, cornea, sclera, etc.—may also be taken with the camera.

Meetings of Other Societies

American Physical Society, June 14–16, Schenectady, N.Y.

American Physical Society, June 25–28, Vancouver, Canada

American Institute of Electrical Engineers, June 25–29, Toronto, Canada

Illuminating Engineering Society, Aug. 27–30, Washington, D.C.

Biological Photographic Association, 21st Annual Meeting, Sept. 12–14, Kenmore Hotel, Boston, Mass.

Theatre Equipment and Supply Manufacturers' Association (in conjunction with Theatre Equipment Dealers), Oct. 11–13, Ambassador Hotel, Los Angeles, Calif.

National Electronics Conference, Seventh Annual Conference, Oct. 22–24, Edgewater Beach Hotel, Chicago. The conference is sponsored by the American Institute of Electrical Engineers, Institute of Radio Engineers, Illinois Institute of Technology, Northwestern University and the University of Illinois, with participation by the University of Wisconsin and the Society of Motion Picture and Television Engineers.

The American Institute of Physics is holding a twentieth anniversary meeting in Chicago on October 23–27. Its member societies will hold meetings at that time as follows:

- Acoustical Society of America, Oct. 23–25
- Optical Society of America, Oct. 23–25
- Society of Rheology, Oct. 24–26
- American Physical Society, Oct 25–27
- American Association of Physics Teachers, Oct. 25–27

Society of Motion Picture and Television Engineers

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Technicolor Motion Picture Corp.
Terrytoons, Inc.
Theatre Holding Corporation
Theatre Owners of America, Inc.
Titra Film Laboratories, Inc.
United Amusement Corp., Ltd.
Westinghouse Electric Corporation
Westrex Corporation
Wilding Picture Productions, Inc.